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APRIL 1925

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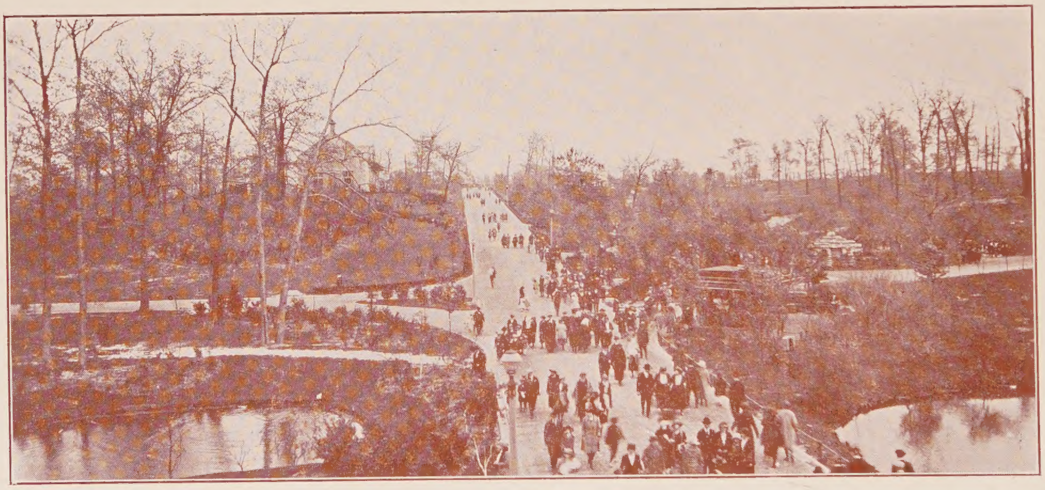
SPRING CONVENTION NUMBER

Spring Convention of the A. I. E. E.

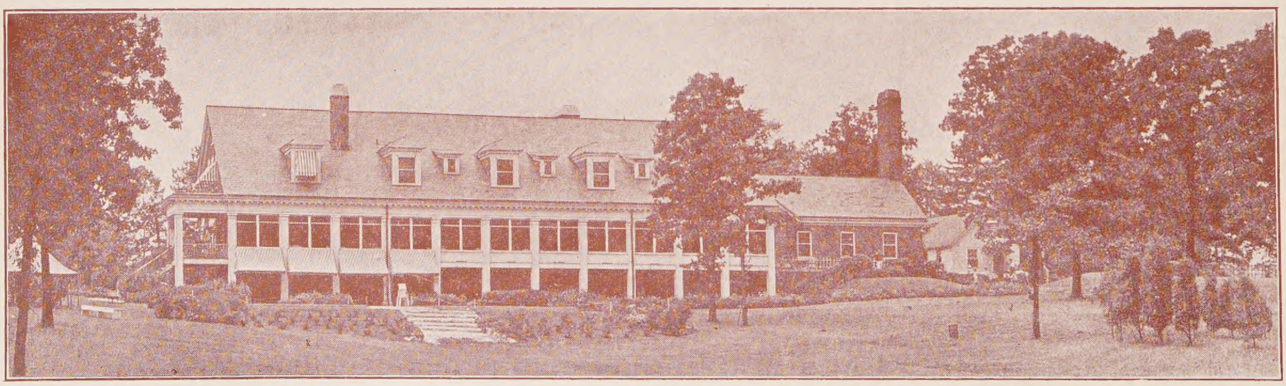
St. Louis, Mo., April 13-17

Views of Convention Headquarters and Surroundings

Chase Hotel Facing Forest Park which Contains the Art Museum, Jefferson Memorial, Zoological Gardens, Municipal Theater, and Home of the Missouri Historical Society



Winter Scene in Forest Park Near Convention Headquarters



Algonquin Golf Club 15 Minutes Walk from Chase Hotel

JOURNAL

OF THE

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Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

Vol. XLIV APRIL, 1925 Number 4

Keep At It Everlastingly

For several years the officers of the four Founder Societies have been endeavoring to bring to the attention of the public the usefulness of the combined training and experience of the engineering profession.

In the latter part of 1924 a statement of policy of procedure for local joint activity was agreed upon by the governing bodies of the four Founder Societies, copy of which may be obtained upon request to the headquarters offices of the respective societies in the Engineering Building in New York.

In several cities engineers have acted jointly in the forming of an intelligent and constructive opinion on important local matters where an engineering opinion was valuable.

The engineer, usually engrossed in the activity of his own individual field of work, does not as a rule give much heed to local civic affairs, either city or state, with the result that the public in general has never realized the help to be obtained from this technically trained, varied experienced group of citizens, the engineers.

Further, the engineers have placed themselves in a position of apparently lacking interest in matters outside their technical field, much to their own discredit, and quite in contrast to the activity of other professional groups.

Progress is at last being made by the engineers through joint activity; but it is not sufficient as the civic duty of the engineer merely to take up problems as they may be thrust upon him for consideration, often too late to be given the careful deliberation they deserve.

One organization, representing the local sections of all national societies, other associations, and engineering clubs, should constantly have before it some local civic matter of mutual interest to engineers and the general public, to be oriented from time to time in joint meeting, often with the public sitting in, that the profession may perform its rightful duty and the people brought to a realization of the possibility of helpfulness from the combined thought of this highly trained group of men.

A specific problem solved and then forgotten is not sufficient, because a continuous effort in this sort of activity is essential to place the engineer, individually and collectively, in a position best to render the service he owes to his locality, his state, and ultimately the nation.

FARLEY OSGOOD

Excellent Discussion At Midwinter Convention

A very noteworthy feature of the recent Midwinter Convention was the excellence of the discussion of the technical papers. A majority of this discussion had been carefully prepared beforehand and this resulted in logical and valuable presentation of the important points. Such careful preparation insures that disconnected and unimportant discussion will be omitted.

It is well however to call attention to one fact in connection with written discussion. This is that the discussion holds interest better if it is spoken from memory as far as possible and reference is made to the written manuscript only at intervals. A discussion read word-for-word without expression will not hold the attention of an audience. Furthermore, in the case of very long written discussion it is well to present to the audience, when possible, only an abstract of the information, reserving the complete discussion for publication.

Earlier Publication of Discussion is Being Attempted

An effort is being made to publish the discussions on papers sooner after a convention than they have been published heretofore. Schedules for each convention will be made allotting a certain length of time for each step preceding the publication. The time allowed by these schedules for handling in headquarters will be cut to a minimum and discussors and authors are requested to help in carrying out the plan.

Cooperation of discussors and authors is absolutely necessary to shortening delay. This can be well understood if the method of handling discussions is known. After receipt from the reporter the typewritten copy of the discussion is sent to the different discussors for correction and condensation. When the corrected discussion is returned it is assembled under the respective papers. It is then usually necessary to have the discussion set in type. Printers proof of the discussion on his paper is then sent to each author to allow him to furnish a closing discussion. The entire discussion is then ready for publication.

These steps of course take considerable time. One discussor's delay in returning his corrections will retard publication of the entire discussion on a paper. For this reason cooperation of all is a necessity.

With the proposed schedules and the cooperation of all discussors it is possible that discussion will be

published in some cases in the third issue of the JOURNAL after the Convention closes. The fourth issue should hold most of the remainder.

Some Leaders of the A. I. E. E.

Carl Hering, the thirteenth president of the Institute, was born in Philadelphia, on March 29, 1860. He graduated from the University of Pennsylvania with the degree of B. S., in 1880, later (1883-84) taking a special course in Electricity at Darmstadt, Germany. From the University of Pennsylvania he received the post graduate M. E. degree in 1887, and the honorary degree of D. Sc., in 1912.

For several years Mr. Hering served as instructor at the University of Pennsylvania and as the first assistant to Prof. Kitler at the Polytechnicum, Darmstadt. In 1884-85 he served as chief engineer for Henry Moehring & Co., Frankfort-on-Main, later returning to Philadelphia, Penna., where he engaged in the practise of consulting engineering, which work he has continued up to the present time. In this work he has specialized in the engineering of electric furnaces, underground electrolysis, and electrochemical processes, and also carried on much original research work in connection with electrophysics.

His work in electric furnaces began in the year 1900, with tests for the reduction of arsenic ores. In 1909 he applied some of his discoveries to the design of electric furnace which are now widely used. He is the discoverer of certain laws of physics, the "pinch effect" a new thermal law and others.

In the year 1884, at the Electrical Exposition in Philadelphia, of which he was the assistant electrical engineer, he started the first comparative life tests of incandescent lamps. His technical writings, which have been voluminous, aimed at bridging the gap between pure and applied science.

Dr. Hering was a delegate of the United States Government, the American Institute of Electrical Engineers, and the Franklin Institute to various Expositions and International Congresses, including the electrical exhibition in Vienna, in 1883, the Paris Expositions in 1889 and 1900, the International Electrical Congress at Paris in 1900, and was a juror of awards at nine other Expositions.

In the year 1889 Dr. Hering was decorated by the Government of France with the order of: Officer de l'Instruction Publique, and in 1901 with the Legion d'Honneur.

Dr. Hering served as President of the A. I. E. E. throughout the term 1900-1901. He was a founder and President of the American Electrochemical Society, 1906-1907; President of the Engineers Club of Philadelphia, 1904, and of the Physics Club, Philadelphia, 1918.

Dr. Hering is an honorary member of several important technical and scientific societies.

U. S. National Committee of the International Electrotechnical Commission

A meeting of the U. S. National Committee of the I. E. C. was held at Institute Headquarters in New York City on Wednesday, March 25, 1925. The meeting was an important one inasmuch as it was practically the final meeting that it will be possible to hold prior to the departure of the delegates for the Conference to be held at The Hague, Holland, from April 16-23, 1925.

The Guidance of Work Committee, under Mr. L. T. Robinson, presented a very comprehensive analysis of the various subjects that have been considered by the U. S. National Committee, with particular reference to the ones that are scheduled for attention at the coming Conference at The Hague.

Where the status of the particular subject permitted, specific instructions were given to the delegates for their guidance in presenting the point of view or proposals of the United States.

Where the subject was still in a formative or possibly debatable condition with no definite opinion on this side, the delegates were provided with data which would represent the best thought in the United States which could be considered of information and guidance to the other National Committees in considering the same subject.

The delegates who will attend the Conference, representing the United States, are as follows:

Dr. C. H. Sharp, President of the U. S. National Committee.

Dr. C. O. Mailloux, Honorary President of the Electrotechnical Commission and Honorary President of the U. S. National Committee.

Mr. C. E. Skinner, Westinghouse Electric & Manufacturing Co.

Mr. L. L. Elden, Edison Electric Company of Boston.

Mr. S. E. Doane, Chief Engineer, National Lamp Works, Nela Park, Cleveland, Ohio.

Mr. E. A. Synder, General Electric Company, Pittsfield, Mass.

A representative of the Electric Power Club, to be designated.

A representative of the Telephone Interests, to be designated.

The actual program of the meetings and subjects is as indicated below:

MEETING OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION

The tentative program for the Convention of the International Electrotechnical Commission Advisory Committees, to be held at the Hague, April 16-23, 1925, includes the following subjects: traction motors, symbols, terminal markings, ratings, rules and regulations, standard pressures, prime movers, transformer oils, lamps, caps and nomenclature.

A Two-Speed Salient-Pole Synchronous Motor

BY ROBERT W. WIESEMAN[1]

Associate, A. I. E. E.

Synopsis.—*The design features and performance characteristics of salient-pole synchronous motors are well known and have been thoroughly covered in the technical press. The synchronous motor has been handicapped in the past because it is inherently a single-speed machine, and a change in speed could be obtained only by a change in the frequency of the power supply. Changing the frequency, however, is not practical in most applications.*

The special pole described in this paper which allows two-speed operation of a synchronous motor to be obtained at high efficiency is a new feature[2]. The same principle applied to a generator enables two frequencies to be obtained at the same speed or the same frequency at two different speeds. All that is necessary to change the speed (or frequency) is a pole-changing switch for the stator winding and a reversing switch for the rotor winding. A 5000/2500-h. p., 600/300-rev. per min., two-speed synchronous motor was built without having first constructed a model of any kind. This motor proved to be entirely satisfactory and its characteristics obtained by test agreed very closely with the calculated characteristics.

At either speed the two-speed synchronous motor functions exactly as the ordinary synchronous motor. There is nothing special or complicated about its construction, it does not require any more attention than the ordinary synchronous motor, and its expense of maintenance is just the same. The first cost of such a motor is only slightly more than that of the ordinary synchronous motor whose rating is equal to the low-speed rating of the two-speed motor. Therefore, the two-speed synchronous motor is a practical machine and it should open a new field for synchronous motor application.

* * * * *

Purpose

THE purpose of this paper is to present the theory of the two-speed (constant torque) salient-pole synchronous motor, to describe a 5000/2500-h. p., 600/300-rev. per min., unity power-factor, 60-cycle, 2300-volt machine of this type. It will also be shown that its characteristics can be predetermined with the same degree of accuracy as those of the ordinary synchronous motor, and that this machine, when driven at constant speed, can be made to function as a two-frequency generator.

Introduction

The ordinary synchronous motor is inherently a one-speed machine because its revolving field, which is excited by direct current, must rotate in exact synchronism with the gliding magnetomotive force of the stator. Induction motors can be built to operate at two, three, and four speeds because the induction motor has a cylindrical rotor, a uniform air gap, and a distributed rotor winding. These features make it easy to change the synchronous speed by regrouping the stator and the rotor coils. In the synchronous motor with the usual salient-pole construction, the air gap is not uniform and the field winding is concentrated. Therefore, to operate a salient-pole synchronous motor from a constant-frequency supply at more than one synchronous speed, a special design is necessary. Such a motor is particularly suitable for constant-torque loads because synchronous motors are most efficient when operated at normal magnetic flux and current densities at either speed.

The multi-speed synchronous motor can operate at unity power-factor (or at any desired leading power-factor), whereas the multi-speed induction motor usually has a rather low lagging power-factor at the lower speed, unless a special compensating arrangement is used. It will be seen later that the particular two-speed synchronous motor described has an efficiency of 95.6 per cent when operating at 5000 h. p., 600 rev. per min., and at 2500 h. p., 300 rev. per min. It can thus be seen that the possibility of obtaining two speeds from synchronous motors opens a new field of application which so far has been covered by induction motors.

This particular motor (described later) was built to drive an a-c. generator at two speeds in order to obtain two frequencies. This motor can function equally well as a two-frequency generator when driven at constant speed. Thus a frequency converter set, consisting of two of these machines, could supply three different frequencies.

In some mine fan installations the full capacity of the fan is not required at certain periods of the day. In cases where a speed ratio of one to two is satisfactory, the two-speed synchronous motor should be suitable. Although this load would not be a constant-torque load, the efficiency at both speeds could probably be made higher than that of a corresponding two-speed induction motor. Furthermore, the synchronous motor could be operated at any power factor to obtain power factor correction. Thus, at the one-half speed condition only about one-eighth power is required and the remaining synchronous motor capacity can be utilized for power-factor correction. One difficulty in this application is that 100 per cent pull-in torque is required which necessitates a heavy starting winding. The ordinary starting winding can be used if a clutch is installed or if the motor is equipped with a rotating frame (super-synchronous motor).

Synchronous motors are now being used for ship propulsion. Changes in motor speed are accomplished by changing the generator frequency by varying the turbine speed. With a two-speed motor half speed can be obtained at normal frequency. The advantage of this scheme lies in the operation of the steam turbine at normal speed where the efficiency is maximum.

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1. General Electric Co., Schenectady, New York.
2. U. S. Patent No. 1,491,451 April 22, 1924.

To be presented at the Spring Convention of the A. I. E. E., St. Louis, Mo., April 13-17, 1925.

Backwater conditions at certain waterpower plants are such that the effective head is much less (sometimes one-half) during the rainy season than during the dry season. For efficient operation the water turbine speed should be reduced with the head, a condition which gives a much lower turbine speed during the rainy season. In cases where the turbine speed is reduced to one-half, a two-speed generator would give normal frequency at both normal speed and one-half normal speed of the turbine.

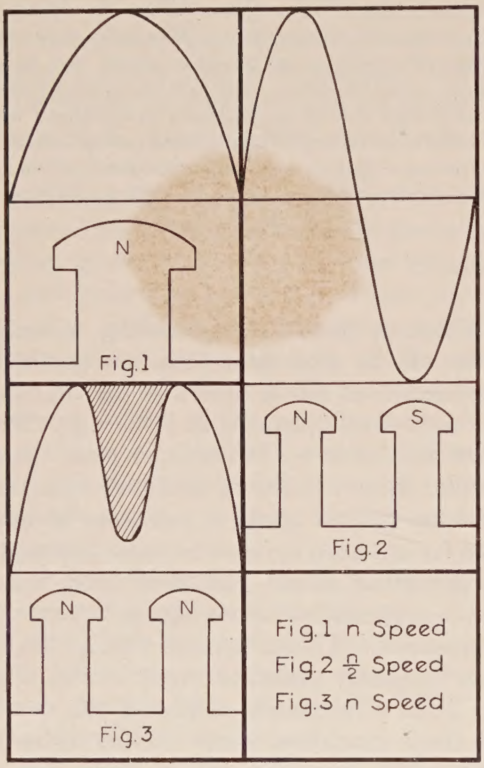


Fig. 1-2—Flux Distribution in the Air Gap of an Ordinary Salient Pole Machine at no Load

Fig. 3—Flux Distribution in the Air Gap of an Ordinary Salient Pole Machine at no Load when One Pole is Reversed

It was originally hoped that the two-speed synchronous motor could be used advantageously for refrigeration. In the summer the ammonia compressors are usually worked continuously at full capacity. In the winter the compressors are unloaded (two-cylinder compressor operated with only one cylinder), a condition which requires abnormally large fly-wheels. Otherwise trouble due to hunting and excessive current pulsations will be experienced. This difficulty is now being overcome by using the modern clearance pockets in the cylinder of the compressor. With a two-speed motor both cylinders could be used at one-half speed which would give the same degree of refrigeration as at full speed with only one cylinder; but about five times the normal speed fly-wheel effect is necessary to prevent excessive current pulsations. Thus the fly-wheel for this condition is nearly as large as the one required when the compressor is unloaded, and the advantage of the two-speed synchronous motor in this case is not so marked.

Special Pole Necessary for Two Speed Operation

Fig. 1 shows diagrammatically the flux distribution in the air gap over a pole-pitch in an ordinary salient-pole synchronous motor. In order to make this machine operate at half of its normal speed, the number of poles must be doubled and the armature winding must be reconnected accordingly. Thus, to have a motor which will operate at normal and one-half normal speed, it is necessary to arrange the armature and field windings so that they can be connected for either normal or twice normal number of poles. Fig. 2 shows the flux distribution in the air gap over two poles of opposite polarity which are placed in the same space as that shown in Fig. 1. This represents at one-half speed the flux distribution, which is the same as in an ordinary machine. Now, to operate this machine (Fig. 2) at normal speed, the polarity of one of the poles must be reversed; the flux distribution will then take the form shown in Fig. 3. This condition gives a flux wave with a pronounced third harmonic which gives a very high core loss due to excessive hysteresis. Furthermore, the flux represented by the shaded area is lost and thus the capacity of the machine is decreased.

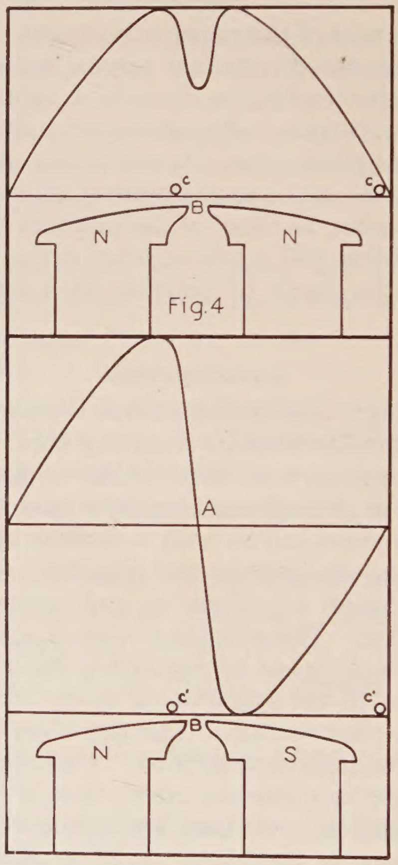


Fig. 4-5—Flux Distribution in the Air Gap of a Salient Pole Machine at no Load with Special Poles at the High and Low Speeds Respcetively

To overcome the objectionable condition shown in Fig. 3, the author devised a special pole piece. Figs. 4 and 5 show the flux distribution in the air gap with this special pole shape for the high and low speeds respectively. Comparing the flux wave of Fig. 4 with that of Fig. 3, it will be apparent that the core loss will be be much less for the flux distribution represented by Fig. 4. Tests have shown that, with the special pole (Fig. 4) at normal speed, the core loss is only 15 per cent greater than that of the ordinary salient-pole machine (Fig. 1); but this is not objectionable. At half speed (Fig. 5) this special pole increases the core loss over that shown in Fig. 2. The hysteresis loss is the same in

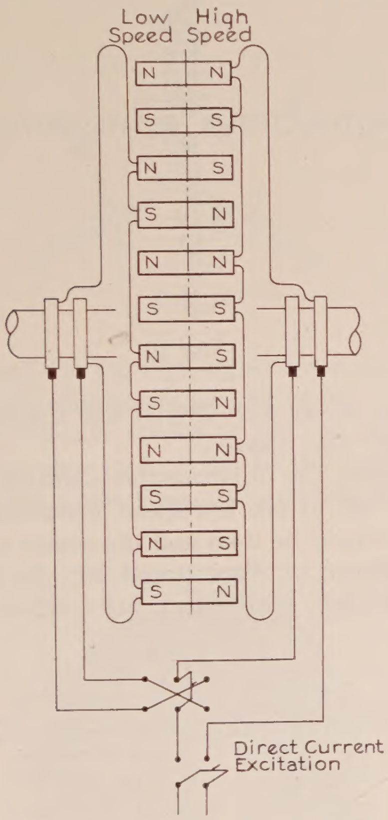


Fig. 6—Method of Changing Poles on the Rotor of a Two-Speed Synchronous Motor

both cases, but the eddy-current loss is greater due to the steep wave front at *A*. Tests show, however, that the core loss for the half speed condition, (Fig. 5), is also only about 15 per cent greater than that of an ordinary salient-pole machine, (Fig. 2). The distance between the poles *B* should be made large enough to prevent a high leakage flux for the low speed condition, (Fig. 5). This leakage flux would be high only in a machine with a very large number of narrow poles. The shape of the pole face is a compromise between the best shapes required at the two speeds respectively. If the motor is to operate most of the time at the high speed, the distance between the pole pieces *B* (Fig. 4) should be made relatively small. Conversely, if the motor is to operate mostly at the low speed, the distance *B* should be increased.

Scheme for Changing Number of Rotor Poles

The scheme for changing the number of effective rotor poles in the ratio of two to one is shown by Fig. 6. The polarity of the polar projections for the high speed is indicated by *N*, *S*, *S*, *N*, etc., to the right of the vertical center line and the polarity for the low speed is indicated

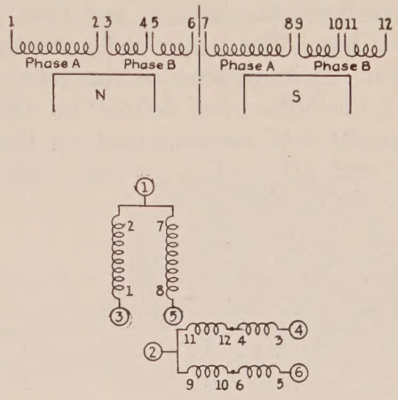


Fig. 7

by *N*, *S*, *N*, *S*, etc., to the left of the vertical center line. To simplify the method of connecting the field coils, half of the coils have their connections made on one end of the rotor and the other half are connected on the opposite end. It should be noted that every other pair of polar projections have the same polarity for both the high and low speed conditions and the field coils in these polar projections are connected to one set of collector

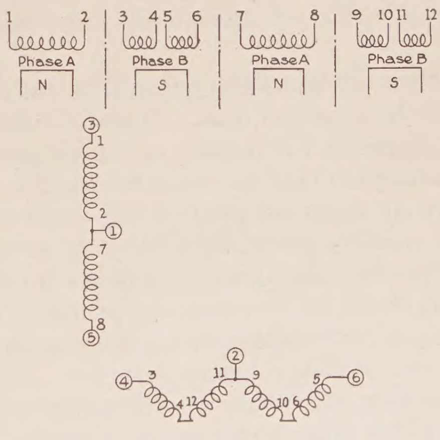


Fig. 8

rings—to the right. The pairs of polar projections whose polarities must be reversed when changing from the high to the low speed, or vice versa, are connected to the other set of collector rings—to the left. The two sets of collector rings are connected in series through a reversing switch. The number of rotor poles is changed in the ratio one to two,—high to low speed, or vice

versa, by throwing the reversing switch to the right or to the left.

Description of Stator

The stator of a two-speed synchronous motor is practically the same as the stator of an ordinary synchronous motor. The stator frame and stator punchings are exactly the same. No special arrangement of the turns or the conductors in the coil is necessary. The only difference is in the stator coils and coil connections. The coils usually have a smaller pitch than those used on ordinary synchronous machines and thus the coil and projection is less. The stator coil pitch can be varied within certain limits to accommodate the conditions of design. At the high-speed connection the coil pitch can be made 50 to 60 per cent (coil $c\,c$, Fig. 4), which makes the pitch 100 to 120 per cent (coil $c'c'$, Fig. 5) at the low speed connection.

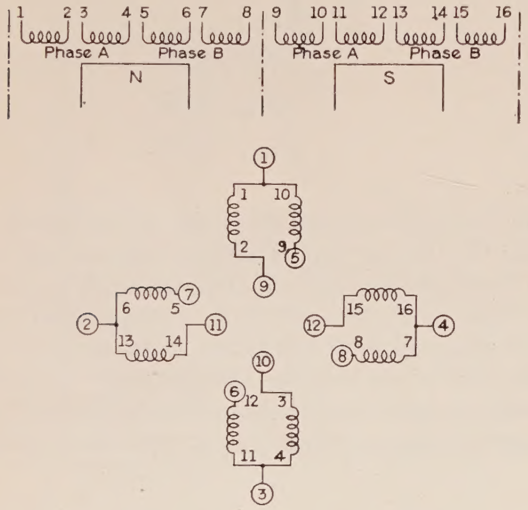


Fig. 9

A-c. motors are usually supplied with electric power from constant potential lines. Since it is desirable to have the magnetic flux density in the air gap approximately the same at both speeds, it follows that the number of turns in series per phase of the stator winding at low speed must be twice the number in series at high speed. Therefore, changing the number of stator poles in the ratio of one to two consists of changing the number of circuits in the ratio of two to one in such a manner that half of the phase groups are reversed. The method of reconnecting one phase of the stator winding by reversing every other phase group is similar to reconnecting the field coils as shown by Fig. 6.

Two-Phase Stator Windings

Figs. 7 and 8 show the method of connecting a two-phase stator winding for the high and low speeds respectively. This connection requires only six terminals and it can be used for either three- or four-wire two-phase. The advantage of this connection is its simplicity. For this reason it is used on induction motors. Its disadvantage is that the phase belt is 180 deg. at the low-speed condition. A 180-deg. phase belt is not recommended for a two-speed synchronous motor because the short-circuit core loss with a 180-deg. phase belt is nearly twice that obtained when the phase belt is 90 deg. Furthermore, the flux per pole is 41 per cent greater with the 180-deg. phase belt, and thus the core

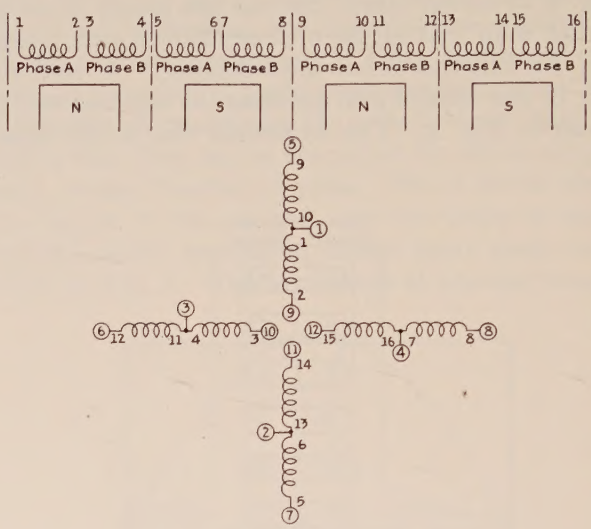


Fig. 10

loss is about 90 per cent greater and the field $R\,I^2$ loss about 250 per cent greater.

To overcome the objectionable features of the 180-deg. phase belt at the low-speed condition, a 90 deg. phase belt should be used and the stator winding connected as shown by Figs. 9 and 10. In Fig. 9, each phase is split into two 45-deg. belts, which become 90

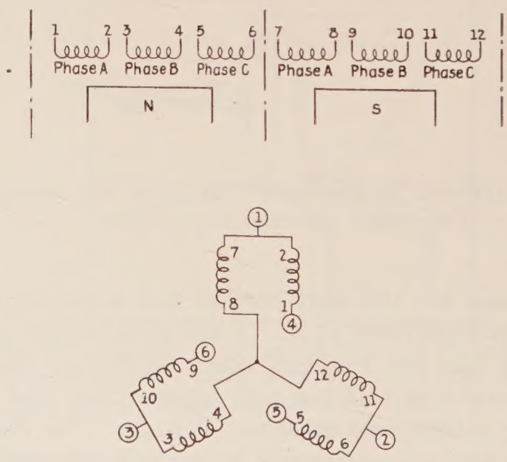


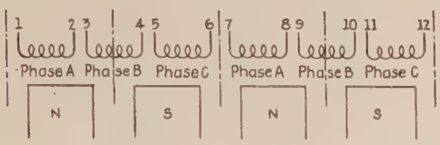
Fig. 11

deg. belts in Fig. 10. Twelve terminals are required when the two-phase power supply is three-wire. If the power supply is four-wire, the leads 9, 10, 11, and 12, (Figs. 9 and 10), can be connected internally and then only eight terminals are necessary. In this case the line terminals for the high speed, Fig. 9, will be 1-3,

2-4, and the leads 5, 6, 7, and 8 are connected. For the low speed, Fig. 10, the lines will be 5-7, 6-8, and no connection will be necessary.

Three-Phase Stator Winding

Figs. 11 and 12 show the wiring diagrams for a three-phase stator winding which requires only six terminals.



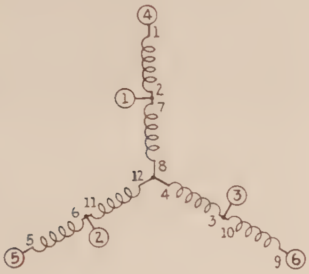


Fig. 12

The phase belt for the high-speed condition is 60 deg. and for the low-speed condition 120 deg. The increase in the phase belt from 60 deg. to 120 deg. helps to counteract the decrease in flux due to the increase of the stator coil pitch when changing from high to low speed.

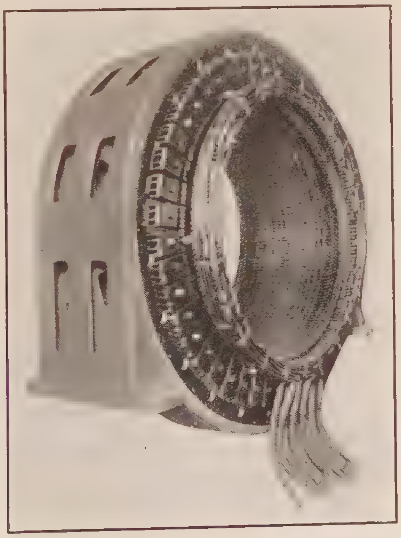


Fig. 13—Stator of a 12/24-Pole, 5000/2500-H. P. 600/300-Rev. per Min. Two-Speed Synchronous Motor

Description of a 5000/2500-H. P., 600/300-Rev. per Min., Two-Speed Synchronous Motor

Fig. 13 shows the stator of a 5000/2500-h. p., 600/300-rev. per min., 12/24-pole, 60-cycle, unity power-factor, two-phase, 2300-volt, two-speed, synchronous motor with the end shields removed. The stator winding is arranged so that a 90-deg. phase belt is obtained at both speeds.

Fig. 14 shows the rotor completely assembled. The poles are equally spaced so that the maximum amount of interpolar space can be utilized for the field coils. This motor is used on a 24,000-kv-a. frequency converter set where it was desirable to place the motor coupling between the rotor and the bearing. In order to reduce the axial length of the set to a minimum, all four collector rings were placed at one end of the rotor. The usual practise is to place the coupling beyond the bearing and then it is desirable to place two collector rings on each side of the rotor.

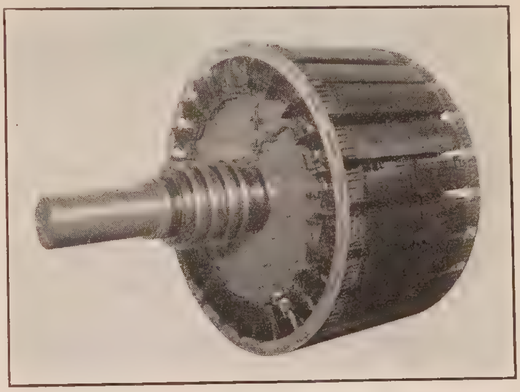


Fig. 14—Rotor of a 12/24-Pole, 5000/2500-H. P. 600/300-Rev. per Min. Two-Speed Synchronous Motor

Fig. 15 gives a section view of the motor showing the unsymmetrical pole tip. The poles are equipped with an amortisseur starting winding, consisting of five bars per pole. Starting tests show that the unsymmetrical pole face has no tendency to cause the motor to lock at a sub-synchronous speed when it is connected for either speed.

An interesting feature in the rotor construction of this two-speed motor is the possibility of arranging the field coils at the high speed connection to form a two-phase winding which would give considerable starting torque when the motor is operated as an induction motor. This can be done by dividing the coils into two independent groups, each group consisting of alternate

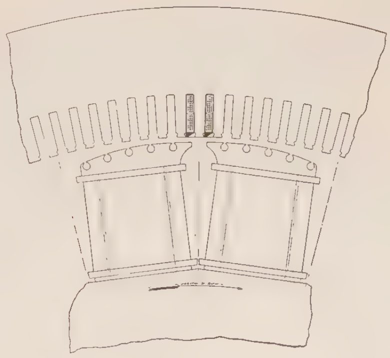


Fig. 15—Section View of Two-Speed Synchronous Motor

coils connected in series, and by short-circuiting the groups separately. The disadvantage of this scheme is that eight collector rings would be required and thus

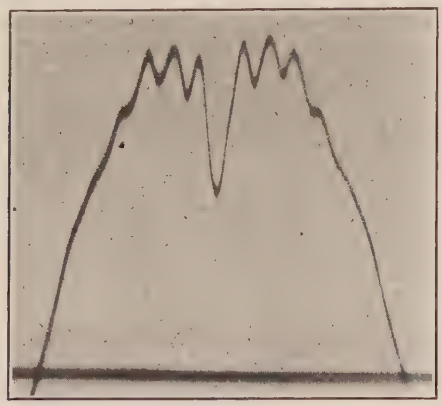


Fig. 16—Flux Wave in Air Gap at High Speed No Load

the axial length of the motor would be materially increased.

Predetermination of Motor Characteristics

The actual flux distribution in the air gap is obtained by taking an oscillogram of the voltage induced in an exploring coil placed on the armature face. Figs. 16 and 17 show the flux waves obtained by tests for the high and low speed conditions respectively.

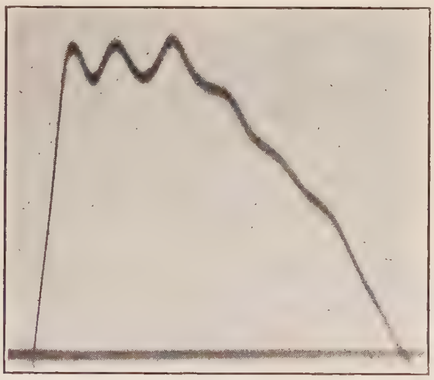


Fig. 17—Flux Wave in Air Gap at Low Speed No Load

Fig. 18 shows the outline of the magnetic field structure drawn to scale. The flux distribution in the air gap is obtained graphically by plotting the equipotential lines of magnetomotive force and the tubes of magnetic flux. The influence of the stator and rotor slots is neglected. The dotted lines in Fig. 18 give the calculated flux distribution in the air gap and the full lines show the flux distribution obtained by test. In plotting the actual flux waves (Figs. 16 and 17) in Fig. 18 the ripples due to the rotor amortisseur winding slots were neglected. It should be noted that in Fig. 18 the full wave (one-half cycle) of the low-speed flux wave is shown and only half (one-quarter cycle) of the high-speed flux wave is shown, since this is a symmetrical wave (Fig. 16). The calculated flux waves agree very closely with those obtained by test. Since the predetermination of the flux distribution in the air gap is the foundation upon which the design calculations are based, it follows that the characteristics of a two-speed synchronous motor can be readily predetermined.

Fig. 19 shows the calculated and test saturation, syn-

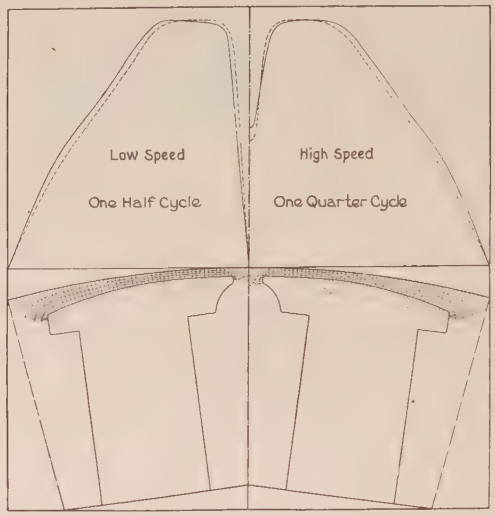


Fig. 18—Flux Distribution in Air Gap at No Load

———— Test
- - - - - - Calculated

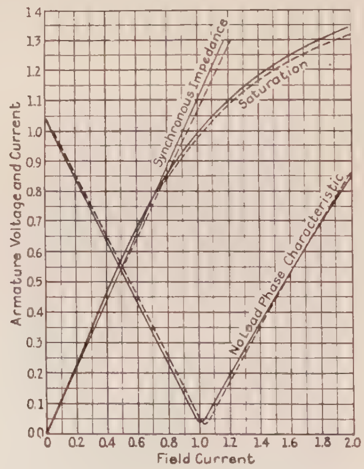


Fig. 19—Characteristic Curves 12/24-Pole 5000/2500-H. P. 600/300-Rev. per Min. Two-Speed Synchronous Motor at 600-Rev. per Min. Normal Voltage

———— Test
- - - - - - Calculated

chronous impedance, and no-load phase characteristic curves for the high-speed condition; Fig. 20 gives similar low-speed characteristics. Figs. 21 and 22 give the starting torque and starting current for the high and low-speed conditions respectively. A comparison of Figs. 21 and 22 will show that the starting torque developed with the high-speed connection is much higher than that developed under the low-speed con-

dition. The flux density in the air gap is higher and the reactance is lower for the high-speed condition, and since the starting torque varies approximately as the square of the flux density and inversely as the reactance, it follows that the high-speed condition should give a higher starting torque.

The efficiency curves of this motor at the high and low speeds are shown in Fig. 23. These efficiencies were obtained experimentally by the segregated-loss method and they include the windage and friction loss, open-circuit core loss, short-circuit core loss, armature and field $R\,I^2$ losses. These efficiency curves show that at normal load the efficiency is about the same at both speeds. This refers to 5000 h. p., 600 rev. per min., and to 2500 h. p., 300 rev. per min. The stator $R\,I^2$ losses are about the same in either case, but the windage and core losses are much less at the low speed. This accounts for the high efficiency at the low speed.

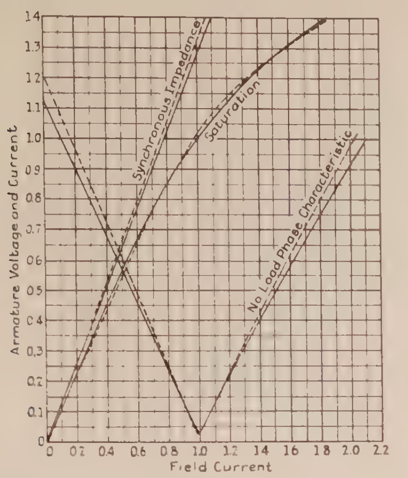


Fig. 20—Characteristic Curves 12/24-Pole 5000/2500-H. P. 600/300-Rev. per Min. Two-Speed Synchronous Motor at 300-Rev. per Min. Normal Voltage

——————— Test

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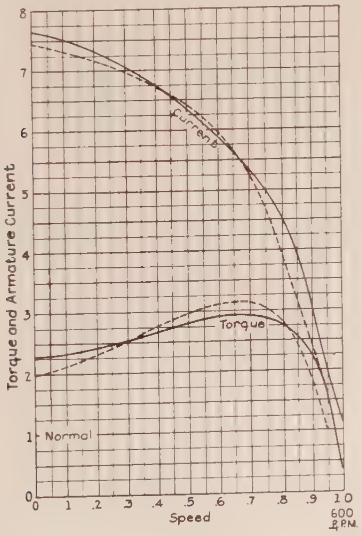

Fig. 21—Starting Torque 12/24 Pole 5000/2500-H. P. 600/300-Rev. per Min. Two-Speed Synchronous Motor Normal Voltage 600-Rev. per Min. Connection

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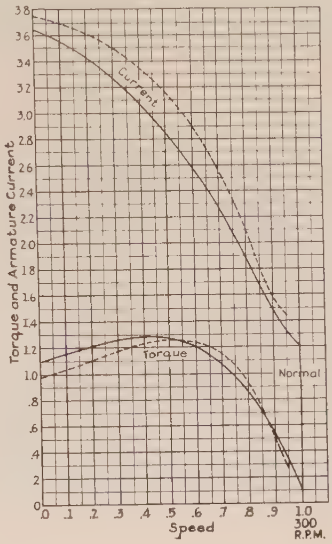

Fig. 22—Starting Torque 12/24 Pole 5000/2500-H. P. 600/300-Rev. per Min. Two-Speed Synchronous Motor Normal Voltage 300-Rev. per Min. Connection

——————— Test

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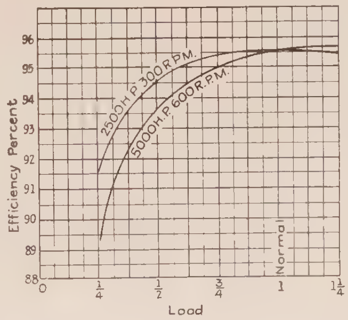


Fig. 23—Efficiency 12/24 Pole 5000/2500-H. P. 600/300 Rev. per Min. Two-Speed Synchronous Motor

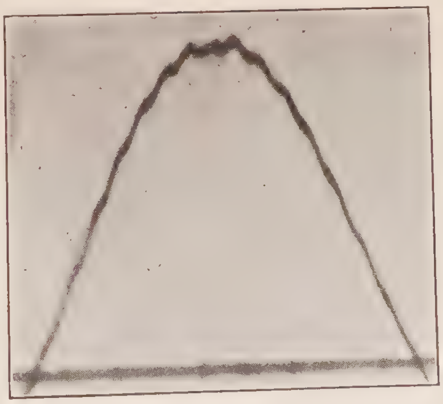


Fig. 24—Voltage Wave at High Speed No-Load

Two Frequency Generator

A two-speed synchronous motor can also function as a two-frequency a-c. generator when driven at constant speed. Although the flux wave at either frequency deviates appreciably from a sine wave, the voltage wave can be made nearly sinusoidal by a suitable choice of the number of slots and of fractional pitch of the armature coils. Fig. 24 shows an oscillogram of the no-load voltage wave when the above described machine is connected for the normal number of poles, and Fig. 25 for twice the normal number of poles. These voltage waves are really good waves when we consider that the machine was connected two-phase and had an integral number of armature coils per pole per phase. The voltage waves would be much better in a three-phase machine with a fractional number of stator coils per pole per phase. By comparing the flux wave, Fig. 16, with its voltage wave, Fig. 24, and similarly, Fig. 17 with Fig. 25, it will be seen how much the pitch and distribution of the armature coils reduce the various flux ripples and harmonics.

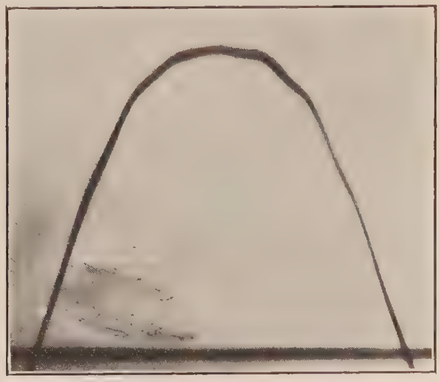


Fig. 25—Voltage Wave at Low Speed No-Load

The efficiency of this machine obtained by test, when used as a multi-frequency generator, is as follows:—

300 Rev. per Min.

12 poles 30 cycles	24 poles 60 cycles
2000 kw., 1.0 P. F.	2000 kw., 1.0 P. F.
Efficiency 95.4 per cent	95.6 per cent

600 Rev. per Min.

12 poles 60 cycles	24 poles 120 cycles
4000 kw., 1.0 P. F.	4000 kw., 1.0 P. F.
Efficiency 95.7 per cent	95.8 per cent

The efficiency at 300 rev. per min., 60 cycles is slightly higher than at 300 rev. per min., 30 cycles because the field $R\, I^2$ loss is less for the 24-pole connection.

Conclusion

There is nothing special or complicated about the construction of the two-speed synchronous motor. Its performance can be predetermined with the same degree of accuracy as that of the ordinary synchronous motor. It does not require any more attention than an ordinary synchronous machine, and its maintenance expense is just the same. The cost of such a motor is only slightly higher than that of an ordinary synchronous motor whose rating is equal to the low-speed rating of the two-speed motor. Therefore, this new synchronous motor is a practical machine and should open a new field for synchronous motor application.

THE SINGLE, STRAIGHT CONDUCTOR AS A NEW FUNDAMENTAL

The *Journal* Franklin Institute for February contains an article by Carl Hering in which he shows how the single, straight conductor can be used as a fundamental, and how simple and well defined its properties are.

Starting with energy (instead of forces) as a fundamental, and a unit length (1 cm.) of a long, straight, conductor, far removed from all other currents, as the most basic, fundamental conductor, using the Northrup formula for the internal pressures (the so-called pinch pressures) in such a conductor, the author shows analytically by a direct, rigid, method, based merely on forces and distances, hence on mere mechanical principles and therefore independent of the self-inductance factor, that the total energy stored (inside and outside) is $i^2/2$ ergs per unit length, the current i being in c.g.s. units. Hence in such a fundamental conductor, half resides inside and half outside; this total energy and the self-inductance are also independent of the radius of the conductor, just as they are known to be for the inside energy. It is shown how the energy of the outside flux manifests itself in the material of the conductor by pressures.

Agreements with other facts are shown, and the reasons for disagreements with some supposedly known facts (based on mathematical infinities) are explained. This stored energy per unit length is a minimum limit in the fundamental conductor and is very small, not infinitely great, as has been believed by some.

The physical meaning of the self-inductance of any part of such a conductor, turns out to be, that it is the distance over which the current flows. The stored energy in any part of such a conductor in ergs, is equivalent to a longitudinal force of $i^2/2$ dynes acting over the length of the conductor in centimeters; this force is independent of the radius of the wire. The field intensity H at the center of a circular circuit of one turn (on which the ampere is based) is π times that at the same distance from such a fundamental conductor. For a unit length, and unit radius of such a conductor, the total radial force (not the pressures) at the outside surface, is i^2 hence is a *unit relation* in the c. g. s. system, which is significant.

It is claimed that these several simple relations of such a fundamental conductor, and its properties, could not have been deduced from the usual "complete circuit" conception, and that such a conductor is a useful unit of reference, as the most fundamental kind of a conductor.

Applications of Motors to Mine Locomotives

BY W. A. CLARK[1]
Associate, A. I. E. E.

***Synopsis.**—This paper discusses the rule of thumb method of applying motors to mine locomotives. It shows why speed of locomotive should be considered in selecting motor horse power. It indicates a rational method of selecting motors for locomotives for general application.*

* * * * *

IN successfully applying a motor to a mine locomotive, it is necessary to have the following information:

Weight of locomotive, gage, limiting height and width, maximum and average grade, minimum radius of curve and service to be performed. The weight required for a given service is determined by the weight required to haul, accelerate or brake the heaviest train on the steepest grade. The minimum radius of curve determines the maximum wheel base allowable. This, with the gage and the limiting height, determines the space available for the motor. The weight and speed of the locomotive determine the approximate horse power of the motor, and the all-day service determines the continuous capacity required of the motor to perform the service without overheating.

All manufacturers of mine locomotives have standardized on certain weights of locomotives and on definite motors for these weights varying with the gage and height limitation. The horse power of the motors for a given weight locomotive is approximately 10 h. p. per ton, but varies from this, depending upon the speed and other conditions. The basis of 10 h. p. per ton was established at the time all manufacturers built non-commutating pole motors, and all locomotives had rated speeds of six to seven mi. per hr. On this basis, the slipping point of the wheels did not require currents in the motors in excess of the commutating range of the motor. Speed should have been considered in selecting the motor horse power in addition to the weight.

If the hour rating current is not exceeded at the rated draw-bar pull of the motor, the motor will never be called upon to operate at currents beyond the commutating range and will have sufficient thermal capacity to stand the accelerating currents.

The horse power is readily determined from the formula:

$$\text{h. p.} = \frac{\text{Tractive effort} \times \text{mi. per hr.}}{375}$$

Tractive effort is equal to draw-bar pull plus locomotive friction, which may be assumed at one per cent or 20 lb. per ton. The rated draw-bar pull with steel tired wheels is 25 per cent of the weight of the locomotive, or 500 lb. per ton. The tractive effort is the sum of these values, or 520 lb. per ton.

1. Of the Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

To be presented at the Spring Convention of the A. I. E. E., St. Louis, Mo., April 13-17, 1925.

Substituting in the above formula it becomes,

$$\text{h. p.} = \frac{520\ T. \times \text{mi. per hr.}}{375}$$

Where T is the tons weight of the locomotive.

This gives the horse power at the wheel, at rated draw-bar pull and speed. However, mine motors are rated in horse power at the pinion, so that to find the motor horse power required, it is necessary to introduce into the formula the gear efficiency. With the standard arrangement of single reduction spur gear this is considered to be 95 per cent. The formula then becomes:

$$\text{h. p.} = \frac{520\ T \times \text{mi. per hr.}}{.95 \times 375}$$

$$\text{or} \quad \frac{\text{h. p.}}{T} = 1.46 \text{ mi. per hr.}$$

$$\text{or} \quad \frac{\dfrac{\text{h. p.}}{T}}{\text{mi. per hr.}} = 1.46$$

From this formula it is readily seen that if the horse power per ton per mile per hour is 1.5 or more, the hour rating current of the motors will not be exceeded at the rated draw-bar pull. The maximum starting draw-bar pull with steel-tired wheels is 30 to 33 per cent of the weight of the locomotive. The starting draw-bar pull will then be approximately 33/25 = 1.33 times the rated draw-bar pull. Using brakes to hold the wheels from slipping the maximum load on the motor will be the current corresponding to 40 per cent adhesion or 40/25 = 1.6 times the rated draw-bar pull. With motor outputs corresponding to 1.33 and 1.6 times the rated draw-bar pull, the corresponding current in the motors will be approximately 1.25 and 1.45 times the current at rated draw-bar pull. If the motor has a rating of 1.5 h.p. per ton per mile per hour, the maximum overload on the motor will be less than 50 per cent overload. A commutating pole motor will stand 100 per cent overload current for short periods without sparking or injurious heating. Therefore, a commutating pole motor with a horse power rating of considerably less than 1.5 h. p. per ton per mile per hour will be large enough to satisfactorily handle the service provided it has sufficient continuous capacity.

The ability of a motor to perform a given service without overheating depends on the continuous capacity and not on the hourly rating, although with similar designs, the continuous capacity is proportional to the hourly rating. The continuous rating of a mine motor is measured in amperes at reduced voltage in line with the standardization *Rules of the American Institute of Electrical Engineers.* The rating is in amperes so that it may be readily checked against the root-mean-square current as figured or measured for a given service. It is taken at reduced voltage because the average voltage impressed on a motor on a mine locomotive, during a definite time cycle of operation, will be approximately half the trolley voltage, or less, as the locomotive is standing with no voltage on the motors a large proportion of the time and is operating with resistance in series with the motors or with the motors in series during acceleration, at which time the voltage across the terminal of one of the motors is considerably less than the trolley voltage. This neglects the line-drop in the trolley wire from the substation to the locomotive.

The continuous rating will vary with the design and size of the motor. Since it depends principally upon the radiating surface, it will be a smaller percentage of the hour rating current on larger motors than on smaller since the surface per weight, or volume, is less on the larger motor. The continuous rating of an enclosed motor will vary from 30 per cent to 50 per cent of the hour rating current. If ventilating covers are supplied on the motor and the armature is equipped with a fan, the continuous rating will be increased in proportion to the efficiency of the ventilation. However, in a mine, a self-ventilated motor draws in a large amount of sand and coal dust. While the fan will keep the motor cleaner than an enclosed motor, the dirt in the ventilating air has a destructive affect on the surfaces over which it passes.

Another way to increase the continuous rating is the use of forced ventilation. A motor-driven blower is mounted on the locomotive and forces screened air through the main motors. By the use of forced ventilation, the continuous capacity is more than doubled. This method of increasing the continuous capacity has the disadvantage of requiring an additional piece of apparatus on the locomotive with additional space required for mounting the apparatus and the air conduits. On large locomotives this is not a serious disadvantage as it is easier to find place for the blower and air conduits than for the much larger motor required, if the motor were an enclosed motor without ventilation. The blower equipment is standard on the larger three-axle locomotives of several of the larger manufacturers of mine locomotives. It is also used on some smaller three-axle and two-axle locomotives, where mine clearances will not permit the use of an enclosed motor with sufficient continuous capacity to perform the service.

In applying motors to a locomotive for any given service, the first thing to determine is the weight of the locomotive required. As stated in the early part of this paper, this is determined by the weight required to haul, accelerate or brake the heaviest train on the steepest grade. Based on steel-tired wheels and level tangent tracks, the formula for determining the weight of locomotive is as follows:

$$W = \frac{L\,(R + A)}{0.30 \times 2000 - A}$$

Where W is the weight in tons of the locomotive required.

L is the weight in tons of trailing load $= N\,W$ where N is number of cars and W is weight in tons of car.

R is the frictional resistance in pounds per ton of the cars and varies from 15 lb. to 30 lb. depending on the weight of the car and type of bearings.

A is the acceleration resistance. This is 100 for one mi. per hr. per sec. acceleration and is usually taken as 10 or 20, corresponding to an acceleration of 0.1 or 0.2 mi. per hr. per sec.

30 per cent is the starting adhesion with steel tired wheels.

2000 is a factor to give the adhesion in pounds per ton.

Where there are grades, the weight of locomotive required to haul the train up the grade is determined by the formula:

$$W = \frac{L\,(R + G)}{0.25 \times 2000 - G}$$

Where G is the grade resistance in pounds per ton or 20 lb. per per cent grade, and 25 per cent is the running adhesion of the locomotive.

The weight of locomotive necessary to start the train on this grade is determined by the formula:

$$W = \frac{L\,(R + G + A)}{0.30 \times 2000 - (G + A)}$$

A comparison of the last two formulas shows that a locomotive which will haul a train up the grade will have ample capacity for accelerating the train provided the grade is more than one and one-half to two per cent since the increase from 25 to 30 per cent adhesion on starting will more than make up for the addition of the accelerating resistance in the formula, since A is then relatively small in comparison with the sum of $R + G$.

Where the grade is in favor of the load, the formula becomes:

$$W = \frac{L\,(G - R)}{0.20 \times 2000 - G}$$

and to brake the train on the grade:

$$W = \frac{L\,(G + B - R)}{0.20 \times 2000 - (G + B)}$$

Where B is the braking effort in pounds per ton and

equals 100 lb. per ton for a braking rate of one mi. per hr. per sec. or 10 lb. per ton for a braking rate of 0.1 mi. per hr. per sec. From the safety standpoint, the adhesion is taken as 20 per cent. It can, of course, be increased by the use of sand provided the grade is short.

If there are curves in the track of lengths equal to a train length, it is necessary to introduce in the above formulas the curve resistence, as for example,

$$W = \frac{L\,(R + G + C + A)}{0.30 \times 2000 - (G + C + A)}$$

where C is the curve resistance in pounds per ton. Curve resistance in pounds per ton for a train of mine cars may be determined by the formula:

$$\text{curve resistance} = \frac{WB \times 2000}{5 \times R}$$

Where $W\,B$ is the wheel base of the car in feet, and R is the radius of the curve in feet.

Having determined the required weight of the locomotive, it is necessary to determine whether the standard locomotive of the weight required has motors of sufficient capacity for the all-day service. If this is gathering service, it is rather difficult to figure the root-mean-square current of the motor, but the proportion of the time in which the locomotive is operating at high draw bar pull is very low, so that a motor applied in accordance with the formula of 1.5 h. p. per ton per mi. per hr. will have ample capacity for any gathering service, and a motor of smaller horse power than determined by this formula would usually have the required capacity.

In haulage service it is, however, comparatively easy to figure the root-mean-square from the motor curve, the profile and the loads. Where the hauls are not too long or the grades long and steep, the standard motor on the basis of 1.5 h. p. per ton per mi. per hr., or approximately 12 h. p. per ton, will usually have ample capacity for the service. But where the hauls are very long, so that the layover time at the end of the trip is very small in proportion to the total time, the root mean square current may figure higher than the continuous capacity of the standard motor. In this case, it is necessary to use a larger motor than standard for a given weight of locomotive, or apply forced ventilation.

In gathering service, the standard motors have ratings of approximately 10 h. p. per ton of the nominal weight of the locomotive, which is ample for locomotives with rated speeds up to seven mi. per hr. This speed is much higher than necessary for gathering service. Storage battery locomotives with rated speeds at 3½ mi. per hr. are able to gather almost as many cars per day as the higher speed trolley type gathering locomotives. Both speed and horse-power rating of the motors on gathering locomotives can be reduced considerably without reducing the daily output of the locomotive, but with a corresponding reduction in power consumption and peak loads. In gathering service the runs are short, and on most of the runs the load consists of one car followed by a run with the locomotive light. A locomotive which has its speed at rated draw-bar pull of 6½ to 7 mi. per hr. will have a balanced speed running light or with one car on the level, of 10 to 15 mi. per hr. This is a higher speed than can be reached in the short runs in the rooms, so it is necessary to operate with resistance in series with the motor a large percentage of the time. If the motors on gathering locomotives are designed for speeds of four to five mi. per hr. at rated draw-bar pull, the power required from the line will be 20 to 25 per cent less, the motor may have a correspondingly lower rating and the actual time of the trips of the light locomotive or of the locomotive hauling a light load will be approximately the same, since the motor will operate for a large proportion of the time with resistance cut out. On runs with heavy loads, the speed will be reduced, but if feeder capacity is limited, the reduced current draw of the lower speed locomotive will give a higher voltage at the locomotive which will increase the relative speed of the locomotive.

THERMAL EXPANSION OF ALUMINUM AND VARIOUS IMPORTANT ALUMINUM ALLOYS

Scientific Paper of the Bureau of Standards, No. 497, gives data on the linear thermal expansion of 4 samples of aluminum and 51 samples of important aluminum alloys. The preparation, chemical composition, heat treatment, etc., are included. Most of the specimens were examined from room temperature to about 500 deg. cent. Typical expansion curves of the various groups of samples are shown and discussed.

A description of the apparatus used in this research and a review of available information obtained by previous observers on the thermal expansion of aluminum and some of its alloys, are given.

The expansion of cast aluminum (99.95 per cent) from room temperature to 610 deg. cent. is represented by the following equation:

$$L_t = L_0\,[1 + (22.58\,t + 0.00989\,t^2)\,10^{-6}]$$

The relations between the chemical compositions and coefficients of expansion of aluminum-copper alloys (4 to 12 per cent copper) and aluminum-silicon alloys (4 to 12.5 per cent silicon), are shown in figures. The anomalous expansion of two aluminum-zinc alloys at constant temperazure (about 270 deg. cent. on heating) is shown. From the results of previous observers and the present research, it is evident that the aluminum-zinc alloy of eutectoid composition (about 79 per cent zinc) shows the greatest change in expansion at the transformation or eutectoid temperature. A triangular diagram is shown which indicates the effect of change of composition on the coefficients of expansion of aluminum-silicon-copper alloys lying near the aluminum corner of the ternary system. The table in the summary gives a comparison of the average coefficients of expansion of the various groups of samples investigated.

Synchronous Motor Drive for Rubber Mills

With Special Reference to Dynamic Braking Control for Safety Stopping

BY C. W. DRAKE[1]

Member, A. I. E. E.

Synopsis.—Since wound-rotor induction motors with clutch brakes have been very commonly used for this application, a review of the operating conditions and safety requirements is given, in order to show why synchronous motors without clutches may be used for the same application.

* * * * *

DURING 1920, the Rubber Sub-Committee of the Industrial and Domestic Power Committee of the A. I. E. E. collected and prepared considerable data relative to the choice and selection of motors for mill-line drives (paper presented January 14, 1921 at the Akron-Cleveland meeting). It was mentioned in this report that synchronous motors had certain desirable characteristics for mill-line drives and that there were a few in operation which had given very satisfactory service. The real demand for synchronous motors, however, has come only since the interest in power factor improvement has been given thoughtful consideration.

Mill-line drives may be divided into two groups, namely, the geared type, in which gear units with high or moderate speed motors are used, and the gearless type, in which the motors operate at the speed of the mill line or about 100 rev. per min. For the latter group, synchronous motors have been used principally on account of their lower cost and better performance as compared with induction motors, while those synchronous motors which have been used for gear drive were undoubtedly installed primarily for power factor purposes, since there is little advantage in efficiency or difference in cost as compared with the induction motor.

Rubber mill drives impose two severe conditions upon the motor equipment, first, a high starting torque when the mills are started with rubber in the rolls, and second, a quick stopping in case of accident or emergency. The risk and danger involved in the milling of rubber has been appreciated ever since the industry started, and these factors have always had an important bearing on the type of driving equipment used. In other words, the question of safety to employees has had, as it rightly should have had, preference over other factors in the layout of mill drives. A knowledge of these conditions explains why the wound-rotor induction motor, which has been most extensively used for mill drives, has in most cases been equipped with a clutch brake. From the standpoint of starting and running the clutch is unnecessary, as such motors have ample starting torque. However, since most of the stored energy of the system is in the rotor of the motor, it is not surprising to find that one of the first methods of obtaining quicker stopping was to disconnect the motor and then apply a brake on the remaining load. Although clutch brakes have been quite generally used, it has been found in many cases that it is the practise in starting to close the clutch first and then start the motor, thus using the clutch only as a safety feature and saving the wear which would be occasioned during starting to the clutch lining.

In view of the established or common practise employed in the installation of wound-rotor motors, it was to be expected that synchronous motors which had lower starting torque and, as a rule, more stored energy, would be equipped with similar clutch brakes, and that these would be used both during starting and stopping. Thus equipped, the synchronous motor should give service identical to that of the induction motor, since each may be designed for the same maximum torque, although the fact that the induction motor slows down considerably before reaching its maximum torque may sometimes give sufficient warning to prevent its pulling out and stalling. Many of the early installations of synchronous motors were of the gearless type, and since motors as slow as this have a low starting torque, the clutches were undoubtedly needed to obtain a starting torque comparable with that developed by the wound-rotor motors. Synchronous motors used with gear units have much higher starting torque but the question is just how much torque is required to start a mill line.

Under normal conditions the mills are started empty, since the rubber is always removed before shutting down at the end of each shift. The torque required to start an empty mill line is so low that it may be entirely neglected. If the mill line is shut down by accidentally pulling the safety switch or by loss of voltage, the torque required to start the mills will depend upon the condition of the rubber in the mills at that time, and that may take from 50 per cent to 150 per cent of full-load torque. If the motor is shut down due to pulling out or the opening of the overload relay, which is usually set at about 200 per cent load, it is evident that if the motor cannot carry the load at synchronous speed, it cannot start it from rest, and one must resort to other means in order to reduce the load. The most usual method is to reverse the motor, thus backing up the rubber in the mills. Depending on conditions, the rubber may

1. Westinghouse Elec. & Mfg. Co. East Pittsburgh, Pa.

To be presented at the Spring Convention of the A. I. E. E., St. Louis, Mo., April 13-17, 1925.

either be removed if very stiff and cold, or, after again starting the motor in the normal direction, the rubber may be forced through the rolls, since by this method the motor gets a start before the rubber enters the wedge of the rolls. Experience has proven that with a motor of correct capacity for a given mill line the shut downs with loaded mills are not numerous, and consequently the question of starting torque should not unduly affect the rating or design of the motor. Synchronous motors designed to operate at 80 per cent power factor and at a speed of about 600 rev. per min., which is commonly used for geared drive, have a starting torque on full voltage varying from about 1.5 times full load torque for motors of 100 h. p. up to about 2.5 times full load torque for motors of 400 or 500 h. p. capacity. When started on the 80 per cent voltage tap of the starting transformer a torque varying from 1.0 to 1.5 times full load torque will actually be obtained, and although this is not as high as could be obtained by a wound-rotor motor or by a clutch, it has been found sufficient to meet all requirements.

As long as a clutch was thought necessary to obtain sufficient starting torque, the simplest, and probably the cheapest, method of obtaining safety stopping was by means of a brake on the mill side of the clutch. The

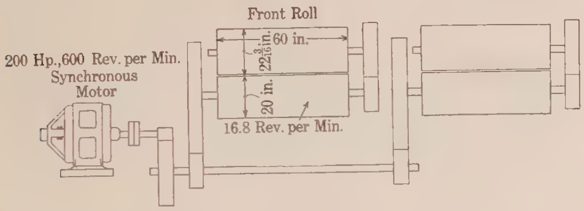


FIG. 1—SCHEMATIC ARRANGEMENT OF TWO 60-IN. MILLS WITH COUPLED TYPE SYNCHRONOUS MOTOR

elimination of the clutch gave opportunity for other methods of braking, and electrical engineers naturally considered first the possibilities of electrical systems. Tests conducted a number of years ago on synchronous motors proved conclusively that very quick and uniform stopping could be accomplished by disconnecting the motor armature from the a-c. supply, and connecting it to a resistance of suitable value, while the field circuit of the motor is left energized at its normal full load value. Although the above facts and principles were known many years ago, it is only during the last two or three years that practical application has been made of them in the rubber industry, and to the best of the author's knowledge, no other industry has attempted a similar application.

Fig. 1 shows a characteristic layout of two 60 in. mills, which, in this case, are driven by a 200-h. p., 80 per cent power factor, synchronous motor, three-phase, 440-volt, 60-cycle, 600 rev. per min. This motor is connected to the gear unit by means of a flexible coupling and when delivering 200 b. h. p. will have a leading reactive component of 124 kv-a., while a wound-rotor induction motor of similar rating would have a lagging reactive component of 106 kv-a. Consequently the replacement of an induction motor by a synchronous motor in this case effects a reduction of 124 plus 106 or 230 reactive kv-a. in the total plant load.

The details of a control equipment for a synchronous motor with dynamic braking will vary considerably

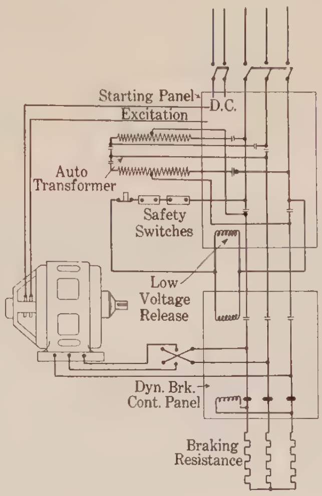


FIG. 2—SCHEMATIC DIAGRAM OF SYNCHRONOUS MOTOR CONTROL SHOWING STARTING PANEL, DYNAMIC BRAKING PANEL AND REVERSING SWITCH

with the size and voltage of the motor, also with the desires of the rubber company, but the fundamentals are the same in all cases. For instance, one company may desire the simplest type of manual starter while another desires a full automatic starter in order to install it in some remote location. Consequently the

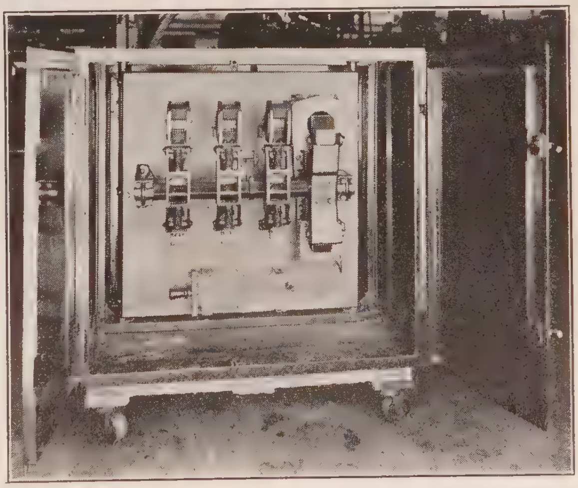
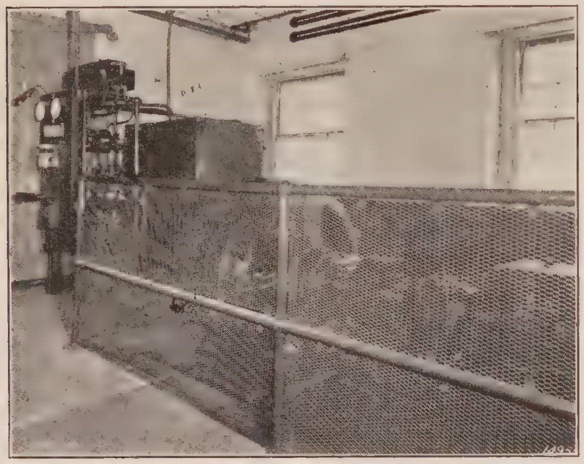
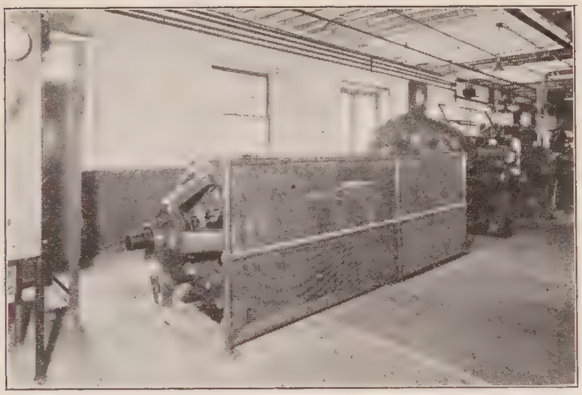


FIG. 3—GRAVITY OPERATED DYNAMIC BRAKING CONTACTOR WITH REVERSING KNIFE SWITCH

dynamic braking contactor has been designed as a separate unit which may be used with any type of starting equipment. Fig. 2 is a schematic or simplified diagram of the control in which the motor starter may be either manual or automatic. The three-pole, double-throw, dynamic braking contactor is really the

heart of the system, for the stopping of the mills in case of emergency is entirely dependent on this and is independent of the rest of the control. As seen from the diagram, also from the photograph of this contactor in Fig. 3, the upper contacts open the circuit to the motor in series with those of the main controller thus introducing a double break and insuring opening the circuit even though the main circuit breaker or contactor does not open. The safety switches, of which there is at least one for each mill, are connected in series and upon the opening of any of these, the circuit is opened to the low-voltage release coil of the starter





FIGS. 4 AND 5—INSTALLATION OF A 200 H.P. SYNCHRONOUS MOTOR WITH DYNAMIC BRAKING CONTROL DRIVING TWO 60-IN. MILLS

and to the upper magnet coil of the dynamic braking contactor. Upon the opening of this circuit the upper contacts open and the lower contacts are instantly closed by the action of gravity aided by the spring pressure of the upper contacts. The closing of these lower contacts connects the motor armature to the dynamic braking resistance, and since the field circuit has not been opened, the voltage generated produces a current, the value of which may be regulated by the value of resistance used. The voltage generated during braking is also utilized to energize the lower magnet and hold the lower contacts firmly together until the motor stops.

The two-pole double-throw knife switch located below the three-pole contactor is used to reverse the direction of rotation of the motor when necessary and this switch is intended to be opened only when the motor is shut down. To provide against opening power current on this switch auxiliary contacts are provided which open the main circuit breaker or contactor of the starting equipment, also the dynamic braking contactor before the knife blades leave the jaws. Fig. 4 and 5 show installation views of a 200-h. p. synchronous motor mill line drive as shown diagrammatically in Fig. 1, together with the starting equipment. The starter is of the manual type panel-mounted consisting of a double-throw oil immersed starting switch with separate mounting auto-transformers, the dynamic braking contactor, reversing knife switch and braking resistance are mounted in the cabinet at the rear of the starting panel.

To obtain the maximum possible safety on a rubber mill drive, the dynamic braking control should:

1. Operate by gravity and not depend upon closing a contactor electrically.

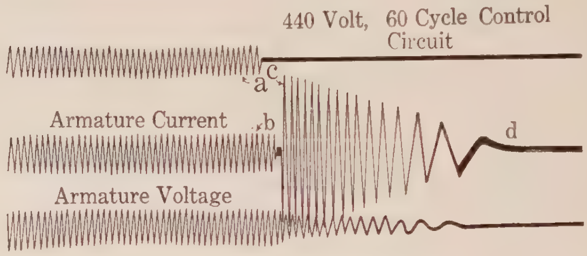


FIG. 6

2. Operate at high speed, in order to obtain as short a stop as possible. The special contactors developed for this work operate upon failure of the control circuit by any cause and, due to the method of construction used, a very high speed is obtained. Tests upon a 500-ampere contactor show a total time from the opening of the control circuit of the upper magnet coil to the closing of the lower contacts of about 1/20 of a second. High speed at this point is of great importance, for until the lower contacts are made, the rubber mills are traveling at full speed. The average speed of the front roll in the present case was about 100 ft. per min. or 20 in. per sec., so that the roll travel from the opening of the safety switch to the close of the dynamic braking curcuit of the motor would be about one inch.

A committee of the National Safety Council has been gathering data regarding the stopping distances of mill lines with a view of eventually preparing a safety code for rubber mills. No conclusions have as yet been reached but the Department of Labor of the State of New Jersey, in a tentative code, has decided upon 18 in. as a maximum travel for group-driven mills with roll diameters from 16 to 24 in. The travel is to be meas-

ured with the mills empty on the surface of the front roll by means of an electrical device which operates when the safety switch circuit is broken. This method of measuring the travel, although it gives the results desired by the safety engineers and the rubber engineers, does not allow the electrical engineer to analyze the entire operation. Consequently, oscillograph records have been taken using three elements and a characteristic film is reproduced in Fig. 6. The upper element indicates the current through the safety switch, the center element the current in the motor armature and the lower one the voltage at the motor terminals. At point *a* the safety switch opened, while the motor current was not interrupted until point *b* was reached. The small gap between *b* and *c* represents the time required by the contactor passing from the upper to the lower position. The distance from *c* to *d* indicates the time for the motor to stop after the braking current is completed, and by counting the number of cycles, it is possible to determine just how many revolutions the motor made. For instance, in this case there are 16 cycles, and since the motor has 12 poles or six cycles per revolution, the total number of revolutions is 16/6 or 2⅔ revolutions. On the mill line under consideration the ratio between the motor speed and the roll travel is approximately 600 rev. per min., to 100 ft. per min., or 10 revolutions equal 20 in. travel. Consequently 2⅔ revolutions represents about 5⅓ inch travel, to which it is necessary to add about one inch for travel during the operation of the controller, making a total travel of approximately 6⅓ in. The time required for the motor to stop can be ajdusted to the maximum torque obtainable by adjusting the braking resistance. Probably the limiting condition in all cases will be the gears and mechanical parts of the mill drive, since the stresses in the motor when stopping in the minimum distance are not greater than those obtained when the motor is pulled out of step, due to overload. As a roll travel of about 10 in. with mills empty, is considered amply safe by motor engineers on mills of large diameter, there is little need of subjecting the equipment to unnecessary strain, and especially since every safety device should be operated and checked at least once a day to see that it is in satisfactory operating condition.

When stopping in a given distance, the dynamic braking will always be easier on the equipment than mechanical braking, since the torque developed in the motor is transmitted to the revolving field through the flexible medium of a magnetic field as compared with brake lining and mechanical friction in the latter case. Tests have also shown that the current values in the primary winding, when braking, are materially less than when starting under average conditions, so that as far as the motor is concerned, if it is of sufficient capacity to start and operate the mill line satisfactorily, those functions will be more severe than those encountered in stopping by dynamic braking.

THEORY AND PERFORMANCE OF RECTIFIERS

The Bureau of Standards recently completed a study of the performance of rectifiers of the type used for charging storage batteries, and the results are now available in Technologic Paper, No. 265, copies of which may be obtained from the Superintendent of Documents at Washington, D. C.

The demand for small rectifiers has increased greatly during recent years, owing to the large number of small storage batteries employed in connection with radio sets, etc., and because of the growing practise of charging larger batteries at low rates, this practise being known as "trickle charging."

The purpose of the Bureau's investigation was to obtain data on the performance of the most common types of rectifiers on the market, and to explain the principles underlying their operation.

Because of the adaptability of the electrolytic rectifier to the study of the underlying principles of rectification, and also because this type possesses many possibilities for usefulness, a considerable portion of the work was carried out on this type, but magnetic, and ionized-gas-bulb rectifiers were also studied.

The effects of various factors upon the wave-form and degree of rectification were investigated by means of the oscillograph. It was found that the aluminum type of electrolytic rectifier, when properly used, is satisfactory at low rates of charging, such as are required for radio "B" batteries, but its life is short. The tantalum rectifier, which is capable of carrying higher currents, is more resistent to the action of the electrolyte, and therefore has a longer life.

The degree of rectification to be expected under different conditions of line and battery voltage, effect of temperature, and character of circuit are discussed.

Special characteristics to be considered in connection with vibrating and thermionic rectifiers are pointed out, and a set of conventional curves is given which may represent the performance of any rectifier, regardless of its type. The effect of various factors upon rectification is demonstrated by means of numerous oscillograms and diagrams, as well as performance curves.

NIAGARA FALLS TO BE PERMANENTLY LIGHTED

According to a recent announcement permanent illumination is to be provided for Niagara Falls from a battery of twenty-four powerful search lamps which will cast 1,320,000,000 candle power. May 24th is the date set for the completion of the installation and a celebration is being planned by the Niagara Falls Chamber of Commerce for this occasion when this powerful battery of search lamps will be turned on for the first time.

Use of Frequency Changers For Interconnection of Power Systems

BY H. R. WOODROW[1]

Fellow, A. I. E. E.

FOLLOWING an extensive study into the cost of power as delivered to the customer, the Brooklyn Edison Company adopted the policy of supplying all the increase in business at 60-cycle alternating-current and curtailing the direct-current load within the capacity of the existing substations. With the 25-cycle generation confined primarily to the supply of power to the direct-current system all new prime movers are being installed with 60-cycle generators. The 25-cycle system is therefore left in a position of barely holding its own.

The new 60-cycle developments being considerably more economical than the old 25-cycle, there is a large economy factor in carrying the maximum amount of the combined system load on the 60-cycle generators. The installation of frequency changers between the 25- and 60-cycle systems made it possible to carry the base load of the 25-cycle system on the new 60-cycle developments and in addition thereto made it possible to pool the reverses on the two systems thereby giving greater utilization and availability of the generating capacity.

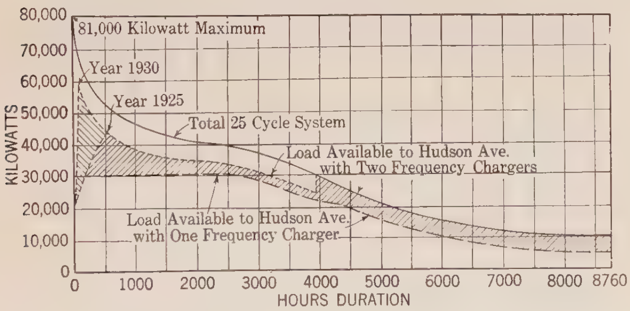


FIG. 1—LOAD-DURATION CURVE OF 25-CYCLE SYSTEM

In Fig. 1 is shown the load-duration curve of the 25-cycle system with amount of load convertible to the 60-cycle prime movers by the installation of first, one 35,000-kv-a. frequency changer; and second, two 35,000-kv-a. frequency changers. The area in the first block represents 160,000,000 kw-hr. per year with a unit cost saving, which for this feature alone, more than pays for the carrying charges and losses of the first frequency changer installation.

The 25-cycle generating capacity amounts to 125,000 kw. with a possible peak load of 85,000 kw. and in addition there is available 15,000 to 20,000 kw. in 25-cycle tie capacity with other companies. The installation of the first frequency changer added 30,000 kw. in reserve generating capacity to the 60-cycle system, and the second unit would add an additional 25,000 to 30,000 kw. This 50,000 to 60,000 kw. of reserve made available to the 60-cycle system is of considerable value with the new 60-cycle generating developments using 50,000-kw. units. This feature alone can easily be said to more than justify the cost of the first frequency changers since the completed installation costs less than $20.00 per kw. while generating station capacity costs upwards of $100.00 per kw., and there was a deficit in 60-cycle generating capacity in 1923.

The frequency changers are of additional value in providing reserve to the 25-cycle plant for a case of unusually bad luck of machine outages in the station.

The metropolitan companies have for a number of years followed the policy of operating at all times with sufficient generating capacity to be capable of carrying the load should the largest generator be dropped from the system. It is, therefore, evident that the continuous parallel operation of the 25- and 60-cycle plants saves the operation of one turbo-generator unit. This permits an economical loading on the units and especially at light load period effects a real saving in production cost.

The installation of the second frequency changer would make it possible to shut down the 25-cycle station for one watch or nearly 3000 hours a year.

The interconnection of systems through frequency changers is of the same general character with similar problems and possible economies as inter-connection of systems through tie lines. The total savings under either condition run into large figures if all concerned cooperate in the operation of the more economical units for base load and shut down the plants and units of less efficiency for use only on peak.

Where two or more companies are concerned in the interconnection, the rate for interchanged power complicates the situation, and it is essential than an equitable rate be established in order to allow operation for maximum economy.

It may be unnecessary to say that the only way to use interconnecting tie lines for obtaining the maximum overall economies is to operate at all times with the systems in parallel. This allows full advantage to be taken of the three separate points previously mentioned, namely:

1. Greatest utilization of the most economical plants and units.

2. Maxumum availability of spare capacity.

1. Brooklyn Edison Co., Brooklyn, N. Y.

To be presented at the Spring Convention of the A. I. E. E., St. Louis, Mo., April 13-17, 1925.

3. Reduction in number and amount of idle or lightly loaded turbo-generator units at all times.

The parallel operation of large systems through frequency changers or tie lines necessitates that these ties have the proper characteristics to hold the systems in step for the major number of operating disturbances. It may not be possible, or even desirable, to hold the systems in step during all disturbances, but it must be a rare case when they are allowed to fall out of step and provisions must be made for the systems to break apart through automatic oil circuit breakers on these rare occasions. Although the Brooklyn Edison Company

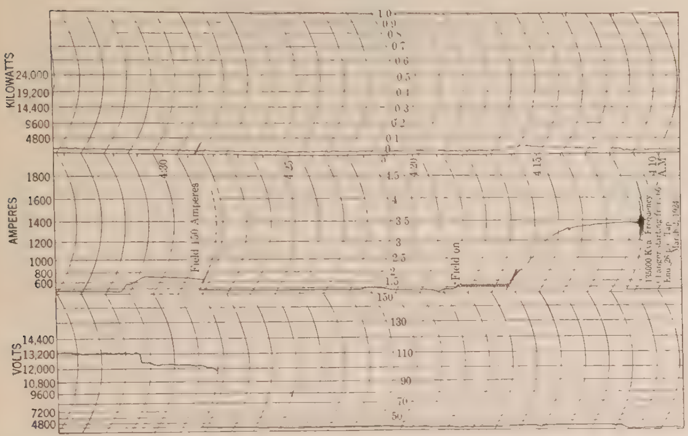


Fig. 2

had a number of smaller frequency changers in operation, converting from 25- to 62½-cycles they were discarded for the larger more efficient unit which would permit parallel operation.

The character of the normal fluctuations of load or disturbances is, therefore, the determining feature of the characteristics of the ties. The loads on both the 25- and 60-cycle systems of the Brooklyn Edison Company are of a rather steady character and the maximum

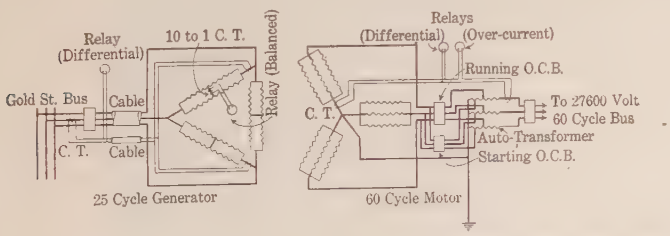


Fig. 3—Relays for Induction Type Motor Shown for One-Phase Only, the Other Two Phases Being the Same

amount of load which can be thrown from one system to the other may be considered as the capacity of the largest 25-cycle unit. This condition may occur were this unit to be automatically tripped from the system, and, as previously stated, this operation is considered a normal function in the metropolitan territory, and, therefore, the two systems should remain in step under these conditions.

When a sudden load is thrown from one system A to another system B, there is necessarily brought about a reduction in the speed of system A to give the phase-angle displacement for transfer of power. It therefore follows, that at the instant when the phase-

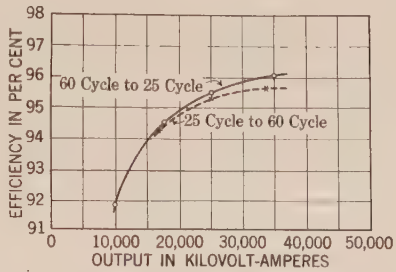


Fig. 4—Efficiency Curves, 35,000-Kv-a. Frequency Changer

angle is reached for the transfer of this amount of power the speed of system A is lower than system B and overshoots the mark. For purely elastic systems, this would require a maximum power transfer of double this value when the oscillations are not accompanied by an impetus at each swing, such as caused by improper governor operation. Tie connections having a maximum synchronizing capacity of double the permissible fluctuation of load should hold the systems in stable operation. Under usual conditions the load on each system provides a dampening characteristic which makes the factor two a rather safe figure to use.

The largest generator on the 25-cycle system of the Brooklyn Edison Company is 30,000 kw. and therefore,

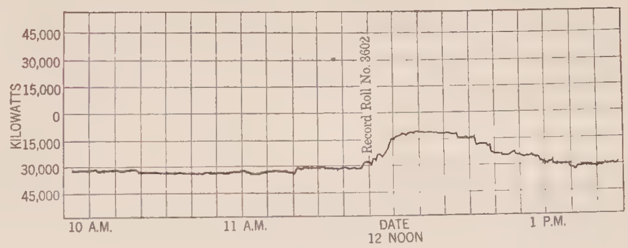


Fig. 5

a frequency changer having a pull-out point above 60,000 kw. was chosen. The 35,000 kw. unit selected has a pull-out point of a little over 70,000 kw. and although a number of system disturbances have occurred while the systems were in parallel through this unit, the two systems have never pulled apart. These disturbances have at times reduced the voltage and as the synchronizing power is a function approaching the square of the line voltage, the synchronizing power at such times was reduced considerably below 70,000 kw. In one case, a direct 3-phase short occurred on the 25-cycle generating station bus with three generators and the frequency changer operating, and although two of the turbine tripped off, the frequency changer and the other generator held in and carried the entire load.

The fluctuation in load through the frequency changer very seldom reaches more than 5000 kilowatts, and in Fig. 2 is shown a typical record of a graphic kilowatt meter in this tie connection.

A one line diagram showing the relay connections on this 35,000-kv-a. frequency changer is given in Fig. 3. The balanced and differential relays are for the protection of the system and the frequency changer in case of short circuits within the machine. The overload relay is for the purpose of automatically tripping out the tie connecting oil circuit breaker in case the two systems fall out of step and the relay is set for sufficient current and time to accomplish this result without tripping out on momentary short circuits.

The synchronous-synchronous type of frequency converter was selected as, for our purpose, it gave the following advantages:

Greater flexibility in voltage control on either system.

Elimination of voltage disturbances passing from one system to the other under short circuit conditions. With somewhat different operating conditions some engineers have felt the electrical tie is an asset under disturbance condition so that a voltage dip will be reflected from one system to the other.

Slightly higher guaranteed efficiency.

The efficiency of the first 35,000-kv-a. unit exceeded the guarantees throughout the full range of operation with the results as shown on Fig. 4.

Amortisseur windings are provided on the 60-cycle end for starting with quarter voltage tap on the transformer whereas the unit when started from the 25-cycle end is connected directly to a turbine with both units started from standstill. In Fig. 5 is shown the current, voltage and kilowatts at the time of starting the frequency changer from the 60-cycle end. The ease with which this machine comes up to full speed is rather remarkable and you will note in the curve at the various points the speed relations of the revolving field with the rotating armature flux as it passes the critical points.

A New Alternating-Current General-Purpose Motor

BY H. WEICHSEL[1]

Fellow, A. I. E. E.

Synopsis.*—The desirability of motors possessing the good characteristics of induction motors and being capable of operating with leading power factor is pointed out. A new machine is described which operates as self-excited synchronous motor under normal operating conditions. During the starting period and excess overloads, it has the characteristics of an induction motor with wound secondary. The machine has excellent starting and synchronizing torque with a small current draw. The electrical and mechanical phenomena, during the starting and synchronizing periods, are discussed. The size of the machine is nearly equal to that of a slip-ring induction motor of equal rating, and the full-load efficiency is approximately equal to that of a corresponding induction motor. It is shown that the overall efficiency of a plant, consisting of squirrel-cage motors and this new type of motor, is usually higher than that of an equivalent plant using induction motors only, correcting the power factor by idle running correcting devices.*

FROM the first days of the successful commercial introduction of the polyphase a-c. system of distribution to comparatively recent days, only the following types of polyphase a-c. motors were in extensive use:

a. The well-known squirrel-cage motor.

b. The induction motor with wound secondary.

c. The conventional form of synchronous motor.

In the majority of installations, either the squirrel-cage or wound rotor type of induction motor is used. The power factor of these installations is usually very poor, especially when the installation contains a number of slow-speed machines.

In the case of squirrel-cage motor installation, it is quite common practise to select the size of the motor according to the starting-torque requirements rather than the running requirements. This results in overmotoring the plant and decreases the power factor still further.

The serious operating difficulties and excess investment and operating costs resulting from poor power factor are fully known and will not be discussed in this paper.

The conventional type of synchronous motor is free of the shortcoming of poor power factor, but it has the following objectionable features:

a. The starting performance is poor.

b. A separate d-c. excitation is required.

c. It is not suitable for very fluctuating loads, especially if the peak loads materially exceed the normal ratings.

In recent years the demand for a motor free of the shortcomings of the synchronous motor and those of the induction motor has grown more insistent. The central station industry is urgently demanding such a machine.

The company with which the author is identified has

1. Of the Wagner Electric Corporation, St. Louis, Mo.

Abridgment of paper presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 9, 1925. Complete copies available upon application at headquarters.

developed a new type of motor which fulfills the above mentioned requirements. This machine, the subject of the present paper, is known as the "Fynn-Weichsel Motor."

The outstanding characteristics of this new motor are as follows:

1. It operates over the whole working range with

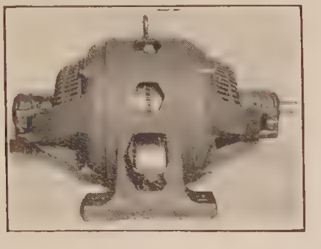


Fig. 1—100-h. p., Eight-Pole, 60-Cycle, Three-Phase Motor

leading or unity power factor. Therefore, when operated in parallel with induction motors, the leading power factor of this motor counteracts the lagging power factor of the induction motors.

2. The starting characteristics are as excellent as those of an induction motor with wound secondary.

3. It is able to operate at very heavy temporary overloads.

4. It operates from no load to about 150 to 200 pre cent load as a synchronour motor. When loaded beyond this value, it continues as an induction motor. If the load is again decreased to about 150 to 200 per cent, it automatically returns to synchronous operation.

Figs. 1, 2, and 3 show the general view and the stator

Fig. 2—Stator of 100-h. p., Eight-Pole, 60-Cycle, Three-Phase Motor

and rotor construction of a 100-h. p., 900-rev. per min. machine of this new type. The rotor is provided with slip-rings and a small commutator. It carries a small d-c. winding which is connected to the commutator and the main a-c. winding which is connected to the slip-rings. The stator is identical to a polyphase induction-motor stator. It is provided with two windings, F and A, as shown in Fig. 5c, 90 electrical degrees displaced from each other.

The connection of the machine is given in Fig. 5c. The auxiliary winding, A, is closed over a resistance and the field winding, F, is connected in series with the commutator brushes, and also in series with a resistance. The axis of the commutator brushes forms an angle less than 90 deg. with the axis of the F winding.

During the starting period of the machine, the resistances in the A and F circuit are gradually decreased and short-circuited in the running connection.

At standstill, the voltage across the commutator brushes is very small in comparison with the voltage induced in the F winding. Therefore, the current flow, and consequently the torque of the machine, is barely influenced by the voltage due to the commuted winding. However, at higher speeds, this condition changes, as the voltage across the commutator is independent of the speed while the voltage induced in the F winding decreases with increasing speed, as shown in Fig. 7. The voltage induced in the F winding is given by the equation:

$$E_x = E_0 \frac{n_0 - n_x}{n_0}$$

E_0 = voltage induced in the secondary when armature is at standstill.

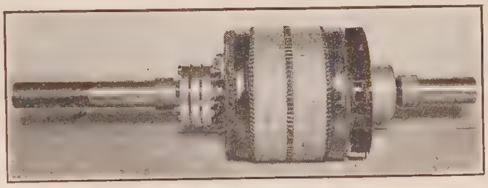


Fig. 3—Rotor of 100 h. p., Eight-Pole, 60-Cycle, Three-Phase Motor

E_x = voltage induced in the secondary when armature rotates with the speed n_x.

n_0 = synchronous speed of the motor.

Let E_c be the constant voltage across the commutator brushes, then the total voltage in the F circuit is given by:

$$E_F = E_0 \frac{n_0 - n_x}{n_0} + E_c$$

Therefore, the current flowing at a given speed, n_x, is given by:

$$T_x = \frac{1}{r}\left[E_0 \left(\frac{n_0 - n_x}{n_0} \right) + E_c \right]$$

where r represents the resistance of the F circuit, the reactance being neglected.

This equation shows that at higher speeds the current is materially larger when the commuted winding is in circuit than when the F winding is short-circuited over itself. But increased current at a given speed means increased torque at this speed. This influence of the injected voltage becomes very marked when the arma-

ture rotates near synchronous speed. Therefore, the influence of this commutator voltage on the torque characteristics of the machine must increase very rapidly with the increasing speed of the armature; *i. e.*, with decreasing slip of the armature. This means that, for a given useful mechanical torque, the machine operates at a higher speed when the commuted winding is connected in circuit than when the F winding is short-circuited. This is, roughly speaking, the reason this type of machine has such excellent synchronizing characteristics[2].

In a standard induction motor, the torque produced by a phase of the secondary winding is, at any time, proportional to the product of the current in this winding and a voltage of the same frequency as the current, the maximum value of this voltage being equal to that of the induced voltage at standstill. The phase relation between the secondary current and this imaginary

Starting Connections

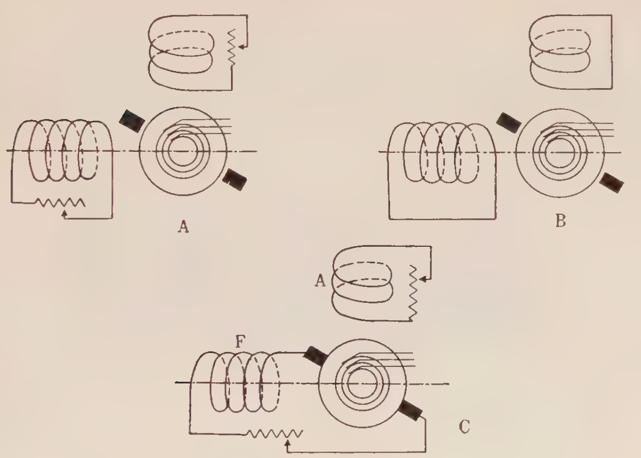


FIG. 5

voltage is equal to that of the current in respect to the actual voltage induced in the secondary at the speed under consideration.

This law is proved in Appendix 1 of the main article.

If the secondary winding is of the two-phase type, then Fig. 8A represents the torque relations of the phase No. 1 and Fig. 8B represents the torque relations of phase No. 2, as derived by aid of the above law. The torque of phase No. 2 is 90 electrical degrees displaced from the torque due to phase No. 1. When both phases have the same resistance, the torque values of both phases are alike. The summation of the torques, $T-1$ and $T-2$, gives the resultant induction motor torque, which is a constant value as long as the resistance of both secondary phases are alike.

If an additional e. m. f. is injected into phase No. 1, and this injected e. m. f. has the same frequency and same phase relation as the induced voltage No. 1-5-3-6-7 in Fig. 8A, then an additional current, $I-3$, flows in this circuit as a result of the injected e. m. f. See Fig. 9A. This current produces a torque, $T-3$, which is superposed over the induction motor torque $T-1$ plus $T-2$. (See Fig. 9C.)

Knowing the speed torque of the machine as induction motor, Curves 1-2-3, Fig. 10, it is possible, from that which has been shown above, to derive the speed-torque

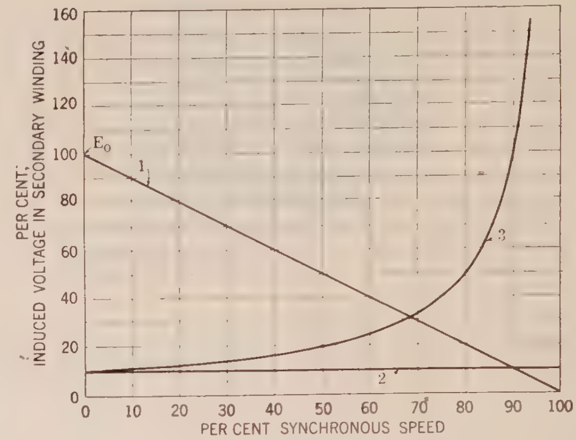


FIG. 7—OPEN CIRCUIT VOLTAGE IN SECONDARY WINDING AND ACROSS COMMUTATOR

E_o = Induced Voltage in Field at Standstill.
1 = Induced Voltage in Secondary E.
2 = Volts Across Commutator in percentage of Induced Secondary Volts at Standstill
3 = Volts across Commutator in percentage of Induced Volts

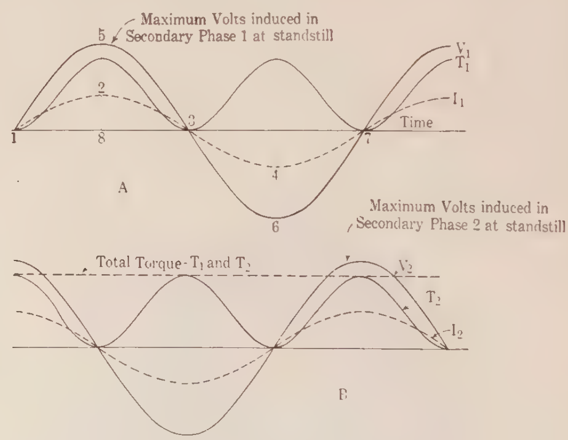


FIG. 8

A. V_1 = Volts Induced in Secondary phase 1 at Standstill
T_1 = Torque of Secondary phase 1
I_1 = Current in Secondary phase 1

B. T_2 — Torque of Secondary phase 2
I_2 — Current in Secondary phase 2

curve of the machine when operated in a connection as given in Fig. 5C. To obtain the torque of the new motor for a given speed, it is necessary to increase the induction-motor torque by the ratio:

$$\frac{E_0\left(\dfrac{n_0-n_x}{n_0}\right)+E_c}{E_0\left(\dfrac{n_0-n_x}{n_0}\right)}$$

2. See paper presented before the Association of Iron and Steel Electrical Engineers, February 16, 1924, "The Motor That Corrects Power Factor" by H. Weichsel.

The torque curves obtained in this manner are Nos. 4, 5, and 6 in Fig. 10. These show that the torques are materially increased when the motor operates near synchronism with only a small amount of resistance in the circuit. Curve 6 intersects the horizontal line at

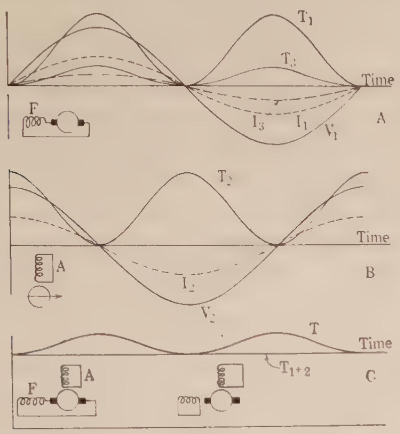


FIG. 9 —A. TORQUES PRODUCED BY SECONDARY WINDING F

T_2 — Induction Motor Torque

T_3 — Torque Due to Interjected Current

I_2 — Induced Current in F Winding

I_3 — Injected Current in Secondary Winding F, by commutated Winding

B. TORQUE PRODUCED BY SECONDARY WINDING A

T_1 — Induction Motor Torque

I_1 — Induced Current in Secondary Winding A

C. TORQUE PRODUCED BY WINDINGS A AND F

T_{1+2} — Resultant Torque $T_1 + T_2$

T — Final Torque Acting to Produce Rotation $T_1 - T_2 - T_3$

point A, which means that the machine used as an example can synchronize with a torque of 230 per cent. The additional torque given by the shaded area in Fig. 10 varies with time, as shown in Fig. 11. The nearer the machine approaches synchronism, the larger the time between two torque maxima.

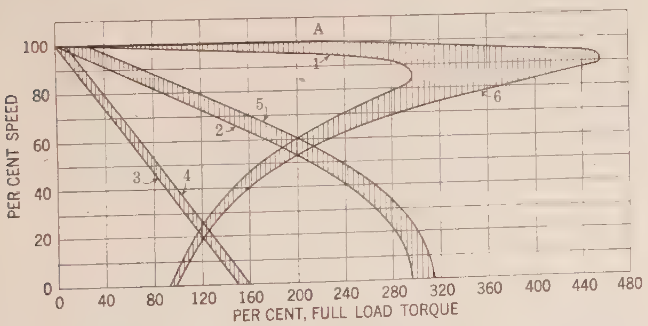


FIG. 10—SPEED TORQUE CURVES OF FYNN-WEICHSEL MOTOR

1—Operating as Induction Motor—no External Resistance in Circuit

2—Sufficient Resistance to Give Maximum Starting Torque

3—Resistance Necessary to Start 150 per cent. Torque

If the load to be accelerated by the armature has a large amount of inertia, then the average available torque for acceleration lies half way between the induction-motor speed-torque, Curve No. 2, and the speed-duction-motor speed-torque, Curve No. 6 in Fig. 10. If, however, the load is mainly a friction load, then the available torque for acceleration and synchronization is given by Curve No. 6.

In the main article, it has been proven that when the brush axis forms an angle α with the field axis, the maximum of the additional torque, $T - 3$, follows the equation:

$$K_1 \sin^2\left(90 - \frac{\alpha}{2}\right)$$

This has been plotted in Curve 2, Fig. 13.

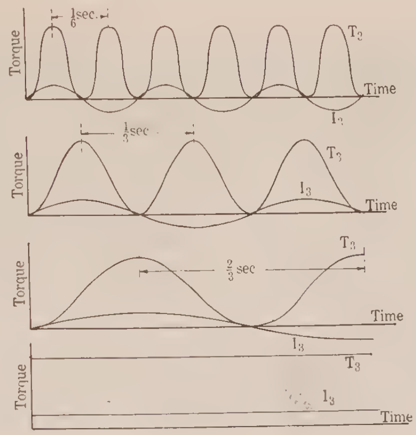


FIG. 11—TORQUE DUE TO INJECTED CURRENT AS A FUNCTION OF SLIP

a. Five per cent. Slip —three ~ per Second in Secondary

b. $2\frac{1}{2}$ per cent. Slip —$1\frac{1}{2}$ ~ per sec. in Secondary

c. $1\frac{1}{4}$ per cent. Slip —0.75 ~ per sec. in Secondary

d. 0 Slip —O ~ per sec. in Secondary

The average torque available follows the equation:

$$K_2' \frac{\cos \alpha}{2}$$

and has been plotted in Curve 1, Fig. 13.

Curve 1 is proportional to the synchronizing torque

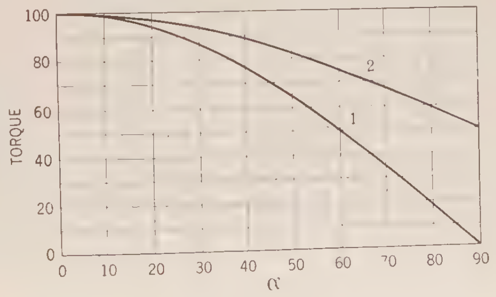


FIG. 13—1. COSINE CURVE
2. SINE² (90 DEG. — $\alpha/2$)

when the load contains a large amount of inertia and Curve 2 represents the synchronizing torque when the load is a friction load.

Fig. 15 is an oscillogram showing the starting conditions of a motor when the commuted winding is not connected in series with the F winding. In other words, when starting as a straight induction motor.

Fig. 15A shows the machine starting under connection according to Fig. 5C. This oscillogram shows that

the starting conditions of the new type of machine are as good as those of a standard slip-ring induction motor.

Fig. 16 represents an oscillogram for the moment when the machine goes from induction-motor operation into synchronous operating with full load on the rotor.

Summing up the main conclusions of the above discussion, the following laws are obtained:

1. The brush displacement from the field axis should be made zero or as small as possible in order to obtain good synchronizing characteristics.

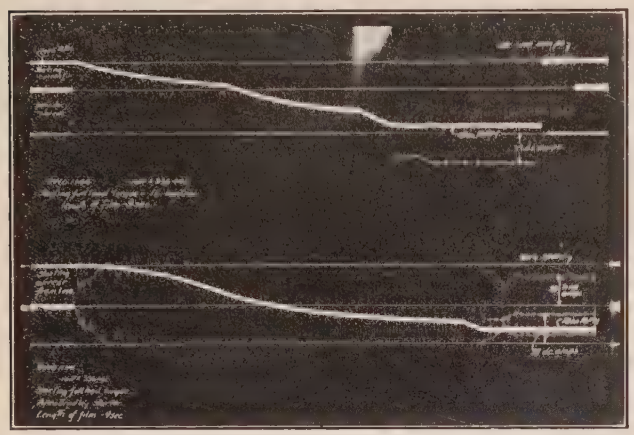


Fig. 15—10-h. p., Four-Pole, 60-Cycle, Three-Phase Motor Starting Full Load Torque Using Carbon Pile Starter

2. The inherent slip of the motor as induction machine should be made as small as is consistent with the general design of the machine.

3. The magnitude of the injected current is a measure of the synchronizing torque and the maximum torque of the machine when operating as synchronous motor.

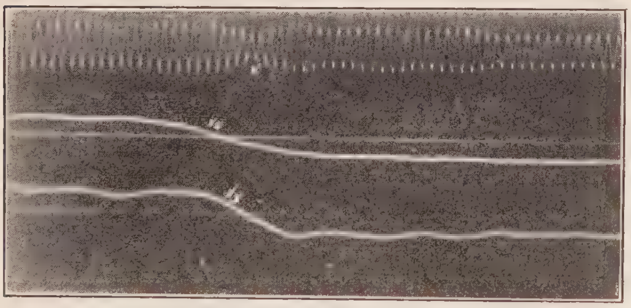


Fig. 16—V1. Shows Current on Motor Circuit When the Motor Returns to Synchronous Operation When Load is Reduced to 150 per Cent

V2. Direct-Current Field-Voltage When the Motor Pulls Back into Step

V3. Direct-Current Field-Amperage When the Motor Pulls Back into Step

If these rules are followed, the machine will synchronize smoothly and operate as synchronous motor under normal load conditions. When overloaded to 150 to 250 per cent, it is pulled out of step but continues to operate very satisfactorily as an induction motor.

Under synchronous operation, a d-c. voltage appears across the commutator brushes for the same reasons as in a synchronous converter. As these brushes are connected with the field winding, F, the machine is a self-excited synchronous motor. The charactersitics of the machine as a synchronous motor are influenced by the angle between the d-c. brush axis and the d-c. field axis. This subject has been treated fully in a paper by V. A. Fynn, presented before the Spring Convention of the A. I. E. E., April 7, 1924, Birmingham, Alabama.

Influence of the Leakage Flux on the D-C. Voltage

The a-c. armature winding produces some magnetic lines which are not interlinked with the stator winding, but which still are interlinked with the d-c. armature winding. The current distribution in the a-c. and d-c.

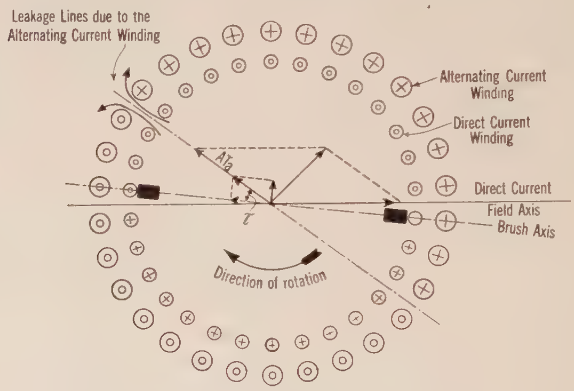


Fig. 19—Influence of Armature Leakage Flux on the Direct-Current Voltage

windings is given in Fig. 19, and from this figure it follows that the leakage lines due to the a-c. winding produce a voltage across the d-c. brushes proportional to:

$$e_L = k \sin (\tau)$$

This voltage can be negative or positive, depending upon the value of the angle τ.

The leakage lines produced by the d-c. winding react on the a-c. winding, but their influence is so small that it can usually be neglected.

D-C. Armature Winding Reaction

The relative position between d-c. and armature field windings remains fixed in space for all load conditions and the same current flows through both windings. Therefore, the resultant d-c. field ampere-turns are the vectorial sum of the armature and stator fields ampere-turns. These resultant d-c. field ampere-turns combine with the total armature ampere-turns, $A\ T\ A_2$, so as to give the resultant ampere-turns, $A\ T\ M$, of the motor.

From the vector diagram, it follows that $A\ T\ A_2$ can be decomposed into $A\ T\ A_1$ and $A\ T\ A_3$, the latter being equal and opposed to the armature d-c. ampere-

turns, $A\,T_{adc}$. This teaches the important fact that *under all conditions the d-c. armature reaction ampere-turns are counterbalanced by equivalent armature a-c. ampere-turns.*

Stator Leakage Lines

While these lines are in existance, they do not influence the running operation of the machine as synchronous motor.

Commutation

Two problems have to be considered:

1. Commutation as far as sparking is concerned.
2. The influence on the operation of the machine as caused by the currents flowing in the short-circuited coils undergoing commutation.

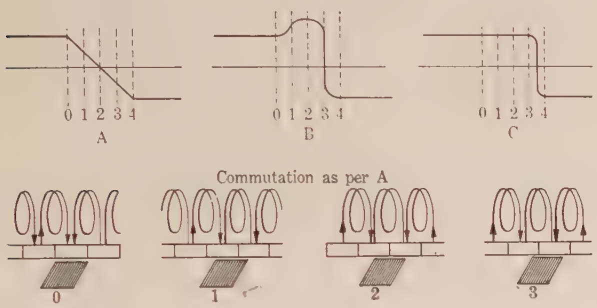


Fig. 22

Position	0	1	2	3
Time	0	1	2	3
Ampere-Turns in Short Circuit Coil	0	+ ½	0	− ½

If straight-line commutation takes place, then the currents undergoing commutation cannot produce any magnetic effect. If, however, the commutation currents follow the law as given in Fig. 22c, a magnetizing effect, due to the commutating currents, will exist. The reasons for this are given in the main paper. Vectorially, this has been shown in Fig. 23, where $A\,T_c$ represents the ampere-turns due to the currents undergoing commutation. In order to keep the total ampere-turns, $A\,T\,M$, of the machine constant, the ampere-turns, $A\,T_c$, must be counterbalanced by a component $A\,T_2$ of the a-c. ampere-turns. This results in bringing the alternating current more into phase with the impressed voltage.

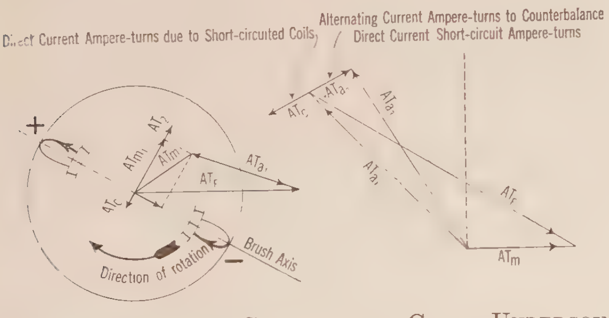


Fig. 23—Effect of Current in Coils Undergoing Commutation

Beside the magnetic effect, the current flowing in the short-circuited coils during commutation produces a certain amount of loss. This loss can be kept very low by properly selecting the voltage between segments. This loss has its maximum at no-load and decreases with increasing load, because the resultant ampere-turns $A\,T\,M$, of the machine nearly coincide with the brush axis at no-load and are practically at right angles with the brush axis at maximum synchronous-motor load.

Sparking

It has been shown that the armature reaction of the d-c. winding is at all load conditions counterbalanced by the a-c. armature ampere-turns. Therefore, the d-c. armature reaction can produce no voltage in the short-circuited coil undergoing commutation. *The machine acts in this respect very similar to a neutralized d-c. machine.* However, a voltage remains which is generated in the short-circuited coil by its movement in the main field of the machine. This voltage decreases with increasing load, as has been explained above, and can always be kept so low that it cannot possibly disturb the commutation of the machine.

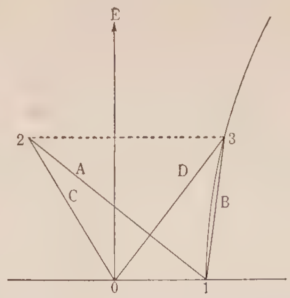


Fig. 24—Comparison of Ampere-Turn Relations in Fynn-Weichsel and Induction Motors

The third voltage, acting on the short-circuited coil, is produced by the leakage lines surrounding this coil when undergoing commutation. These relations are identical to those in a standard d-c. machine.

Losses in Fynn Weichsel Motor

The same kind of losses which exist in standard induction motors exist also in this new type of machine, but the new machine has an additional loss due to the commutator.

Copper Losses

In Fig. 24, 0-2-1 represents a vector diagram of the new machine and 0-3-1 the diagram of the same machine when operating as induction motor. The ratio $\frac{C}{D}$ gives the ratio of the primary ampere-turns,

and the ratio $\frac{A}{B}$ gives the ratio of the d-c. ampere-turns when machine operates as synchronous motor to the secondary ampere-turns when machine operates as

induction motor. As long as ratio $\frac{C}{D}$ remains approximately at unity, the copper losses of the new machine are approximately equal to the copper losses of an induction motor, provided the copper section and mean-turn length are kept the same.

The ratio $\frac{A}{B}$ is usually somewhat larger than unity, but due to the fact that the d-c. field winding in the new type of motor can readily be built with shorter

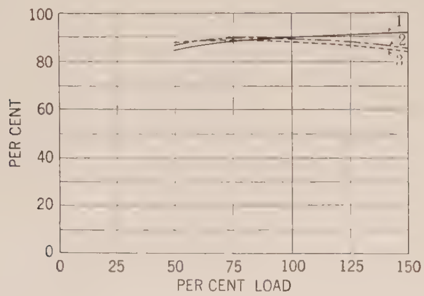


Fig. 26—Efficiencies of 30-h. p., Eight-Pole, 60-Cycle, Three-Phase Motors

1. Fynn-Weichsel 2. Squirrel-Cage 3. Slip Ring

mean-turn length and more copper section per slot than the secondary winding of an induction motor, it follows that the d-c. copper loss will not be materially larger than the secondary loss of the same machine when built as induction motor.

In Appendix 2 of the main article, it is proven that the d-c. ampere turns, A, under otherwise equal conditions, produce the same copper loss as polyphase ampere turns capable of producing the same magnetic effect.

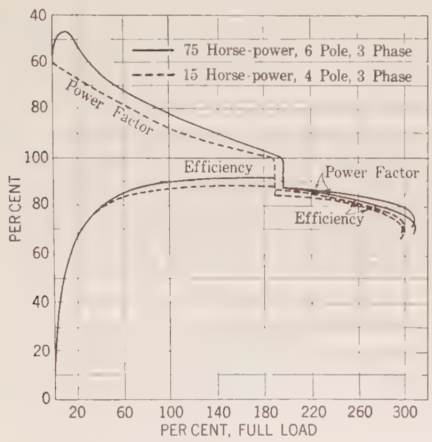


Fig. 28—Comparison of Power Factor and Efficiency of Fynn-Weichsel Motors

Iron Losses

The iron losses in the new machine take place in the rotor, and as this member contains less iron than the stator, it follows that these losses will be less than those in an induction motor.

Commutator Losses

The friction loss due to commutator can be considered as approximately counterbalanced by the gain of the iron losses.

The commutating losses due to the current under-

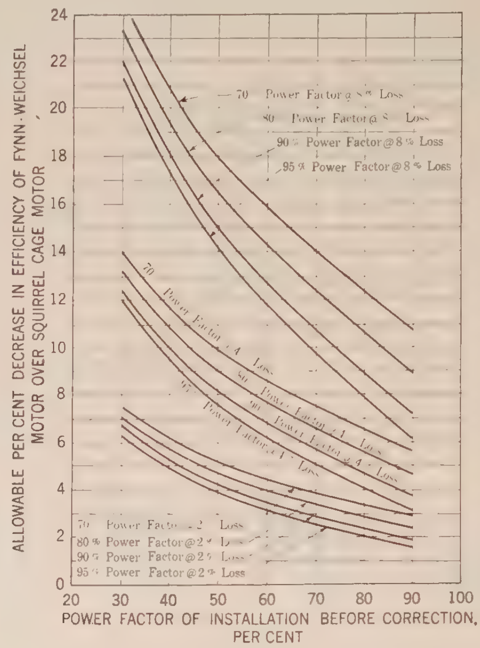


Fig. 37

going commutation can be held very low by properly selecting the voltage between segments.

Stray Losses

As the distribution of the primary and secondary ampere turns in the Fynn-Weichsel motor is identical

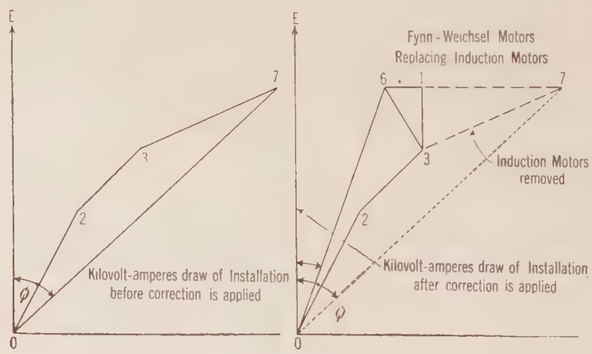


Fig. 39

to that of a standard induction motor, it follows that the stray losses in both machines must be the same.

From the foregoing, it follows that at full load the losses in the new machine must be approximately equal to those of an equivalent induction motor. A further study of the relation shows that there is a tendency for the losses in the Fynn-Weichsel motor to be slightly heavier at fractional loads and slightly lighter at overloads than in a standard induction motor. The correctness of this reasoning is borne out by actual tests.

Fig. 26 gives the comparative efficiencies of a Fynn-Weichsel motor, a squirrel-cage motor, and a slip-ring motor, rated 30 h. p., 900 rev. per min.

Fig. 28 gives the complete performance of a 75 h. p., six-pole, and a 15 h. p., four-pole Fynn-Weichsel motor. A detailed discussion of the operating characteristics of this new type of machine under normal and abnormal line and motor conditions will be found in the *Proceedings* of the Iron and Steel Electrical Engineers of April, 1924, and also in a paper presented before the Franklin Institute on October 30, 1924, by H. Weichsel.

Size of Motor

The losses in the Fynn-Weichsel motor as well as the distribution of primary and secondary ampere-turns are about the same as in a standard induction motor with wound secondary, as has been shown in the preceding. From this follows that the size of this new machine must be the same as for standard slip-ring induction motors.

Application of the Motor

When this new machine operates with leading power factor, it counterbalances the lagging magnetizing current of induction motors operating on the same circuii, and by properly selecting the ratio of the capacity of the new motors to the capacity of the induction motors in a given installation, it is possible to obtain any desired power factor over the whole working range of the installation.

In Appendix 3 of the main article, it is proven that for equal overall efficiency of an installation, once operated by induction motors only with idle running phase-converting devices connected in parallel and once operated by using a combination of squirrel-cage and Fynn-Weichsel motors so as to obtain the same power factor, the efficiency of the Fynn-Weichsel motors could be quite materially below that of corresponding squirrel-cage motors. It has been shown above, however, that the actual difference between the efficiencies of these machines is not very pronounced.

The allowable decrease in efficiency of the new type of motor over the standard induction motors is given in Fig. 37. From these curves it is seen, for instance, that a Fynn-Weichsel motor with a power factor of 80 per cent and an initial power factor of the installation of 60 per cent can have 6.9 per cent lower efficiency than corresponding squirrel-cage motors and still maintain the same overall efficiency of the installation which exists when the installation consists of squirrel-cage motors only and has its power factor corrected by an idle running correcting device which requires 4 per cent loss.

A large number of actual installations are in operation where these new machines are used for driving ice machines, compressors, machine shops, and wire drawing machines, and many other machines found in a variety of industries.

An installation in a marble polishing factory is of particular interest, as in this case the Fynn-Weichsel motors have to accelerate and operate large cast iron tables which contain an enormous amount of inertia.

In another installation, the Fynn-Weichsel motors drive grinding wheels. In this case the load varies greatly and frequently the motors are temporarily loaded beyond their synchronous motor capacity. During this load condition the machines operate as induction motors until the load is eased up to about 150 to 200 per cent of normal, when they return to their synchronous operation. A typical power factor and load curve of this installation is given in Fig. 39. A number of photographs of actual installation are given in the main article.

Electrical Measurement of Physical Values

The Determination by Electrical and Magnetic Means of Quantities not in Themselves of an Electrical Nature

BY PERRY A. BORDEN[1]

Member, A. I. E. E.

THIS paper was prepared under instructions from the Committee on Instruments and Measurements, with a view to forming a basis for the Committee's work in connection with electrical measurements as applied outside of the strictly electrical field. The system of classification used is in accordance with the nature of the quantity under measurement, rather than with the principle involved; and the subject is treated under nine headings.

Measurement of Temperature

There are recognized two principal methods of electrically measuring temperature; the thermo-electric circuit, and the effect of temperature upon the resistance of many conducting materials. Outlines are given of the elementary applications of these, and a number of practical instruments embodying one or the other of the principles are described. Reference is made to

1. Meter Engineer, Hydro-Electric Power Comm. Laboratories, Toronto, Ont., Can.

Abstract of a paper presented at Midwinter Convention of the A. I. E E., New York. N. Y., February 9-12, 1925. Complete copies available upon request at headquarters.

several types of calorimeters embodying electrical methods of temperature measurement, and to hygrometers or humidity meters, in which the principle of the thermocouple has been applied. A brief description is also given of the optical pyrometer.

Measurement of Stress, Strain or Small Changes in Physical Dimensions: General reference is made to the changes which take place in both the electrical and magnetic characteristics of materials when exposed to mechanical stresses, with particular attention given to resistance effects. Several applications of the carbon pile in strain determination are mentioned. Recent developments in the use of the piezo-electric effect of certain crystals are described; and the use of the thermionic tube and its associated circuits for measuring very small dimensional changes is briefly treated. A description of the hot-wire micrometer is given, and a note on the Haigh alternating stress-testing machine. The use of both inductive and resistance circuits in conjunction with the oscillograph for study of vibrations is described: and a reference made to the use of electrical principles in the manometer and engine indicator.

Measurement of Flow

Flow meters are described, making use of the electrical conductivity, the heat capacity and the velocity-head of the fluid under investigation. Prof. Allen's salt-water-velocity method of determining speed of flow in penstocks and conduits is treated. Descriptions are given of a number of flow meters, both for gases and liquids, in which the principle of cooling of a heated conductor is employed, and reference is made to experiments which have been carried out with a view to establishing a definite relationship between the electrical resistance of an electrolyte and its linear velocity past electrodes. Electrical methods of measuring and recording the pressure head due to velocity in a pipe are found in the "Republic" and the General Electric flow meters, both of which are briefly described. Mention is made of a recently developed method of plotting stream-flow diagrams, by reproducing the physical conditions by an electrical system and locating equipotential lines with an alternating current potentiometer.

Measurement of Velocities

The stroboscopic methods of measuring velocities, while not fundamentally electrical, are so closely associated with electrical practice as to receive considerable attention, and the "oscilloscope" for visualizing reciprocating motions is touched upon. The magnetic tachometer and the squirrel-cage speed-indicator are mentioned, as well as the ordinary electrical speed indicators, wherein measurement is made upon the current of a small generator driven by the shaft under measurement. The condenser method of determining linear velocities, and the several inductive methods used in ballistics are treated.

Measurement of Work

No fine distinction is made between work force and energy: and the standard methods of measuring electrical energy with the wattmeter are omitted, as being outside the scope of the paper. Six types of electrical transmission and absorption dynamometers are described, and a reference made to recent tests, in which the characteristics of a steam locomotive were determined by causing it to pull an electric locomotive, measurement being performed upon the regenerated current of the latter. The Gilson device for determining over-all efficiency of a power plant, by balancing in an instrument two electrical forces, one representing the fuel input, and the other the electrical output is briefly treated.

The Measurement of Radiant Energy

Many measurements of radiant energy are made by determining the heat generated when that energy impinges upon a surface; and these would strictly come under the head of temperature measurement. It is realized that it is difficult to apply the term "non-electrical" or "non-magnetic" to any radiant phenomenon: and this section of the paper confines itself to a bare mention of a number of the best known photo-electric cells, used principally in photometry and closely allied work.

Chemical Measurement

The electrical determination of concentration of the hydrogen ion is treated in some detail. The various electrical and magnetic methods of studying and treating the ferrous metals are described, with particular reference to the "hump" method of steel treating. The application of the cooling properties of various gases upon heated wires, is mentioned, and descriptions are given of the CO_2 and CO recorders. Note is made of the firedamp detector, and the dionic water tester.

Navigational Measurements

Coupled with measurements used in navigation are found those used in the detection of hidden conditions, such as the locating of ore bodies and water pockets. The mariner's compass is given as the oldest application of magnetic principles to physical measurements, and mention is made of the very recent application of the earth-inductor both as a compass and as an inclimometer. Special attention is given to those electrical aids to navigation developed under the stimulus of the great war, including the leader cable, radio direction-finding and methods for locating mines, submarines and icebergs, as well as sound-ranging and acoustic methods of measuring ocean depths.

Among the devices for detecting unseen conditions are mentioned the water-vapour detector, the magnetic method of locating flaws in steel, and systems which have been employed in the detection of theft or of the presence of unauthorized persons in certain places. A number of methods, more or less sound, for locating

ore, oil or water deposits, are described in some detail, and under the same head are mentioned such devices as egg testers and sex detectors.

Physiological Measurements

Attention is called to the rapid advances which have lately been made in the application of electrical measurements to the diagnosis of pathological conditions. The method of diagnosing disease by the so-called "method of electronic reactions" is dismissed as not meriting the attention of electrical men until its proponents are prepared to submit a description couched in intelligible terms. Note is made of the value of electrical measurements of temperature in diagnostic work: and the electro-cardiograph is treated fully, both in its application to actual studies of heart performance and in the investigation of psychological conditions. Brief descriptions are given of the "Stethophone" and the "Audiometer," both of which seem destined to fill an important place in diagnosis and medical investigations in general.

In conclusion it is pointed out that the art of applying electrical methods of measurement to work outside of the electrical field is advancing so rapidly as to make it practically impossible that one could keep absolutely up-to-date in his knowledge of all the branches. The general effect is one of bringing together technicians in varied branches of scientific pursuit and finding for them a common ground of thought. Wide and diversified as are the practices of measurement in these branches, it is felt that the Institute forms the natural clearing house for such information; and it is to be hoped now that the ground is fairly well cleared, that the Committee on Instruments and Measurements will be kept cognizant of as many as possible of the new developments which will be made in the application of electrical principles to the measurement of non-electrical quantities.

Acknowledgment is made of the valuable help which has been rendered the author by men both within and without the electrical sphere; and a bibliography of some 250 references is appended.

Mechanical Stresses in Busbar Supports
During Short Circuits

BY O. R. SCHURIG* and M. F. SAYRE†
Member, A. I. E. E. Non-member

THE design of busbar layouts calls for the determination of the stresses occurring in the bus supports during short circuits, because the stresses in question may become sufficiently large to weaken, or even rupture, the supports. Moreover, an understanding of the factors affecting the stresses will often permit the designer to modify the layout so as to reduce the stresses, and thus save material or prevent failure. Hence investigations have been directed towards the calculation of support stresses due to electromagnetic forces caused by short-circuit currents in busbar structures.

The electromagnetic force, as considered within the scope of this paper, is the mechanical push or pull which is caused by the short-circuit current and its magnetic field, and which is exerted on the busbars; *i. e.,* it is the force tending to displace the busbars from their normal position.

The support stress is the mechanical reaction of the support, the reaction being due to the elastic restoring forces set up in the support when deflected; *i. e.,* the tendency of the support to push back towards its position of zero deflection insofar as the tendency is caused entirely by the resilience stored in the support Hence the stress in a support is a direct measure of its approach to failure. For an elastic support, deflected within its elastic limit, the stress is proportional to the deflection regardless of whether the support is at rest or in motion.

The electromagnetic force has been the subject of investigations in the past not only for the case of busbars but also for transformers, current limiting reactors, and disconnecting switches. In the case of busbars, as well as in some of the other cases mentioned, the stresses resulting from the action of the forces applied are very materially affected by the mechanical vibrations produced. The vibrations of the busbar for example have been carefully analyzed by Biermanns‡ who showed that a busbar rigidly supported could be considered as a single-element vibratory system similar to a system comprising a mass suspended from an elastic spring. In the customary busbar structures, however, the supports also are appreciably resilient, so that the busbar-insulator structure must be regarded as a system having two vibratory elements joined together, *i. e.,* a composite structure resembling, for instance, the system comprising a turbine rotor keyed to a flexible shaft, the shaft bearings being attached to an elastic base.

Hence, the determination of short-circuit stresses in

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‡Bibliography, No. 6.

busbar supports involves a study of the transient vibrations occurring in the busbar structure which is essentially a damped mechanical system composed of two vibratory elements and having two interrelated natural frequencies, the system being impelled during short circuits by a decreasing electromagnetic force having a unidirectional component and two harmonic components, one at current frequency and another at twice the current frequency. The electromagnetic force upon the busbar itself is given by a well-known formula, given in equation (**10**), involving only the current magnitude, the conductor spacing, and the length of busbar span. This force, however, acts upon the busbar rather than on the insulator, and the insulator is stressed only indirectly, after a time lag, as a result of the bending of the busbar. Therefore, the likelihood of failure of the support hinges not only on the initial electro-magnetic force but also on the rate of decrement of that force and upon the vibratory characteristics of the busbar-insulator system.

In analytical method of maximum stress calculation based on all of the factors mentioned has been developed and is outlined in the Appendix, for the basic case of a bus structure having long, straight, uniform, parallel busbars with equidistant, rigidly mounted supports of uniform characteristics. The method of calculation is a general one applicable to all cases of elastic busbars intermittently supported, irrespective of whether the conductors are placed face-on or edge-on with respect to the supports and irrespective of whether the supports themselves are stressed in bending tension or compression.

The actual bus structure is, of course, often quite complex involving, for instance, the effects of tap connections, bends, unequal spans, non-uniform current division. Special consideration, may have to be given to these factors in many cases. Moreover, in structures with long spans where the forces so act as to cause relatively large busbar deflections, the tension set up along the busbar may cause large secondary bending stresses in the supports, which stresses act in a direction at right angles to the stresses covered by the formulas developed in the paper. For this type of structure, the secondary stresses have often proved to be the controlling factors in design.

The method of calculation presented here differs from those employed in the past, since the calculations used heretofore have only partially taken into account, or totally neglected, the oscillatory characteristics of busbars and of supports.

Since the natural frequencies of busbar structures range from, say, 10 to 300 cycles per second, mechanical resonance is within common possibility in buses of 25-cycle circuits as well as in buses of 60-cycle circuits. While not all cases of resonance give rise to stresses greatly in excess of those at non-resonance, resonance in some cases multiplies the stresses five or even ten times. It will often be possible by proper methods of design so to change the natural frequencies as to avoid the cases of resonance giving extra heavy stresses.

The analytical equations developed for stress calculation are inherently complex, but their results may be expressed with sufficient accuracy in the form of curves, each group of curves covering a wide range of cases. A representative curve is given in this paper in Fig. 1. The development and use of any practical set of working curves depends in a large measure upon a detailed knowledge of the mechanical characteristics of the structural elements involved.

Practical Formula for Maximum Stress Calculations

The stress formula and the stress curve presented here are based on the following selected conditions:

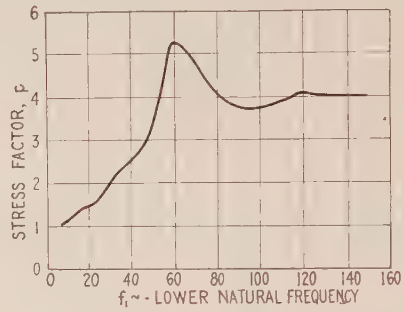

Fig. 1—Curve of Stress Factor p

For the calculation of maximum support stress during 60-cycle short circuits, for values of f_1, lower natural frequency, ranging from 5 to 150 cyc. per sec. and for the value of f_2, higher natural frequency, equal to 180 cyc. per sec. The maximum support stress is $p\,F_0$, where F_0 is the electromagnetic force per busbar span for the initial r. m. s. (total) short-circuit current.

The curve of p is calculated for the following specific constants (see Appendix).

$$n_1 = n_1 = 5$$
$$g = 12.6$$
$$h = 2.2$$

Attention is called to the fact that the two natural frequencies f_1 and f_2 of the assembled busbar-insulator structure often differ very materially from the values of *busbar natural frequency for rigid supports* and of *support natural frequency without the busbar.* The differences in question are due to the support flexibility affecting busbar deflections and due to the busbar mass affecting support vibrations.

A useful formula and a simple chart for the determination of the natural frequency of busbars with rigid supports are given by L. F. Woodruff (Bibliography No. 34), but do not apply to busbar-insulator structures with flexible supports.

Two-wire short circuits with the maximum amount of initial current displacement.

Average initial rates of current decrement applicable without material error to maximum stress determinations for short circuits in systems for which the short-circuit reactance does not exceed, say, 30 per cent.

An average value of mechanical damping applicable to a variety of bus structures having copper bars and porcelain insulators.

The application of the formula and of practical stress curves calls for the following data:

1. Initial value of r. m. s. total short-circuit current I_0, as obtained from accepted short-circuit current decrement curves,* I_0 ampere.

*Bibliography No. 14.

2. Length of busbar span between centers of supports, l in.

3. Dimension of individual busbar lamination (measured in the direction parallel to plane of deflection) a in.

4. Dimension of busbar perpendicular to a, b in.

5. Center spacing between bars (or groups of bars) mounted on separate insulaotrs, s in.

6. The two natural frequencies f_1 and f_2 of the busbar structure; they are most readily obtained by a simple test.

7. The frequency f_c of the current.

The procedure is to calculate F_0, the electromagnetic force exerted on a length of busbar span by the initial r. m. s. value of total short-circuit current, from the formula†

$$F_0 = 4.5 \times 10^{-8} \times k \times I_0^2 \frac{l}{s} \text{ lb. per span‡} \qquad (\mathbf{1})$$

and to obtain the maximum support stress P from the formula

$$P = p\,F_0 \text{ lb. per support} \qquad (\mathbf{2})$$

where p is the stress factor obtained from stress curves

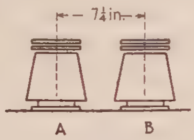

Fig. 2—The Bus Structure Considered in Example

selecting the value of p corresponding to the two natural frequencies of the bus structures. Fig. 1 gives a sample stress curve for 60-cycle currents.

Additional working stress curves, similar to that of Fig. 1, but covering the full range of natural frequencies, or other ranges of conditions, may, of course, be prepared by the same procedure.

Example of Stress Calculations

Two-wire short circuit between phases A and B in Fig. 2 each phase having two copper bars 4 in. by ¼ in., with ¼ in. air space between bars. Calculate the maximum support stress for the following conditions.

$$\begin{aligned} I_0 &= 16{,}200 \text{ amperes} \\ l &= 56 \text{ in.} \\ s &= 7.25 \text{ in.} \\ a &= 4 \text{ in.} \\ b &= \tfrac{1}{4} \text{ in.} \\ f_1 &= 26.5 \text{ cycle per sec.} \\ f_2 &= 280 \text{ cycle per sec.} \\ f_c &= 60 \text{ cycle per sec.} \end{aligned}$$

Then from equation (**1**)

$$F_0 = 4.5 \times 10^{-8} \times k \times I_0^2 \frac{l}{s}$$

where

$k = 1.05$ from H. B. Dwight's chart (Bibl. No. 11)

Hence

$$F_0 = 4.5 \times 10^{-8} \times 1.05 \times 16{,}200^2 \times \frac{56}{7.25} = 96 \text{ lb. per span}$$

and the stress factor p, obtained from a curve similar to that of Fig. 1 (or by calculation from (**12**) is 1.8

Thus the maximum stress per support is

$$P = 1.8 \times 96 = 173 \text{ lb.}$$

A test was made on the bus in question with a 25-cycle current, rather than a 60-cycle current. The test at 25-cycle per sec., gave a measured peak stress of 305 lb., for the same value of initial r. m. s. short-circuit current, *i. e.*, 16,200 amp., as indicated in Fig. 6. The greatly increased stress at 25 cycles is due to nearly perfect resonance, the natural frequency $f_1 = 26.5$ cycle per sec. being practically equal to the frequency of the fundamental component of electromagnetic force. It is therefore seen that in a given bus a short-circuit current of one frequency, say 25 cycle per sec., may produce a much greater stress than the same current of another frequency, say 60 cycles per sec.

Results of Tests

A large number of tests were made to check the stress calculations: 1, on small-scale structures of definitely known and readily adjustable mechanical characteristics and 2, on full-size typical busbar-insulator structures with short-circuit currents up to 25,000 amperes. The results of the tests were in good agreement with the calculations.

The support deflection curve (with time) as well as the busbar deflection curve (with time) were recorded by oscillograph, with the aid of specially designed displacement recorders. Moreover, the deflections of the insulators were measured for slowly applied constant loads, so that the support stresses could be calculated from the oscillographic support deflection records. The bus structures used had five or more uniform busbar spans per phase. The results of one of the tests are given below.

The object of this test was to compare test results of support stress with calculated results for a bus structure employing porcelain insulators with a long busbar span (56 in.) in which the bars were mounted face-down on

†Assuming uniform current distribution in the conductors and neglecting the deflection of the bars. Exact formulas (not generally required in stress calculations) allowing for the deflection of the bars are given by V. Karapetoff in Chap. XIII, The Magnetic Circuit, McGraw-Hill, 1911. See also Biblo. No. 27.

‡The factor k is a shape correction factor. It depends on the width, thickness and spacing of the bars, and allows for the well-known fact that the electromagnetic forces between bars are not always the same as those obtained on the assumption that the entire current is concentrated at the center of each bus. The value of k frequently differs from 1.0, especially in cases of closely spaced bars. The necessary values of k have been calculated and plotted by H. B. Dwight, Bibliography No. 11.

the supports, as shown in Fig. 2. The center spacing between phases was 7.25 in., two 4 in. by ¼ in. bars being used per phase. The two natural frequencies of the structure were 26.5 cycle per sec. and 280 cycle per sec.

In the oscillogram, Fig. 3, are shown in the upper curve the 25-cycle short-circuit current of 14,900 amp. initial r. m. s. value, in the middle curve the center deflection of a busbar span, in the lower curve the support deflection occurring at the level of the busbar. Fig. 4 shows, in the lower part, the support-stress curve, *A*, by test (from Fig. 3) together with a calculated support-stress curve, *B*, calculated for a lower natural frequency of 25 cycle per sec. (by equation (**17**) of the Appendix). In view of the almost perfect resonance obtained in the test, the stress factor for maximum support stress is 3.5, meaning that the maximum support stress is 3.5 times the initial average electromagnetic force per span. Moreover, the maximum support stress is 75 per cent greater than the electromagnetic force calculated from the maximum value of short-circuit current (21,500 amperes) measured at its first peak.

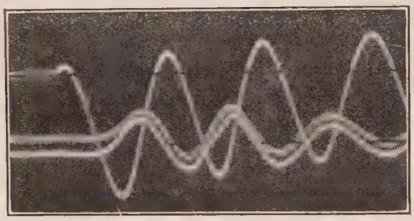

Fig. 3—Oscillogram Pertaining to Test No. 1

Upper Curve: 25-cycle current, initial r. m. s. value 14,900 amperes
Middle curve: Center deflection of busbar span 0.19 in. maximum
Lower Curve: Deflection of support at level of busbar center 0.15 in. maximum

The load-deflection curve for the insulator appears in Fig. 5.

In Fig. 6 reasonably good agreement is shown between test points and a calculated curve of peak stress for short-circuit current values ranging from 8000 to 19,000 amperes, under the conditions of this test.

The authors wish to acknowledge the contributions made towards this work by Messrs. D. Basch, C. W. Frick and L. F. Woodruff.

Appendix

Calculation of Stresses in Bus Supports

It is the object of this appendix to outline a procedure for estimating the maximum short-circuit stresses in busbar supports.

Busbar structures with flexible supports may be treated as a mechanical system comprising a busbar span of concentrated mass M_b, constant stiffness S_b,* and motional resistance, the busbar being held by supports which are also represented by a concentrated mass M_s, a constant stiffness S_s, and motional resistance.

*The stiffness is the force per unit deflection, the force being slowly applied to the mass originally at rest.

The electromagnetic force f per span will be considered as applied to the equivalent busbar mass M_b; while the driving force acting on the support will be $S_b\,y_b$ where y_b is the deflection of the mass M_b with respect to the supports as indicated in Fig. 7.

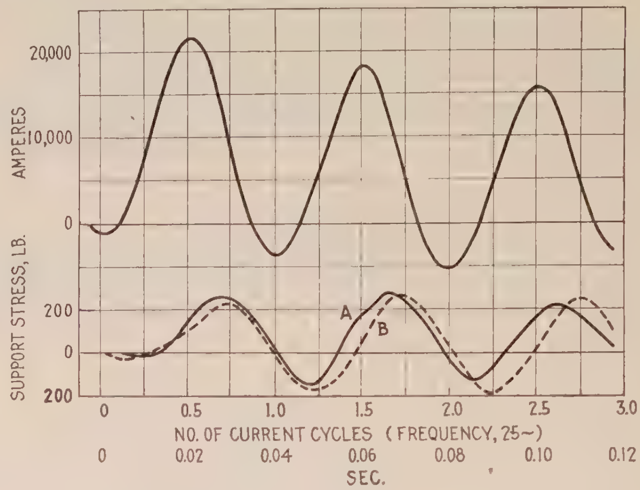

Fig. 4—Current and Stress Curves for Test No. 1

Upper: Current from Fig. 3
Curve A: Support-stress curve by test, from Figs. 3 and 5
Curve B: Calculated support-stress curve, by equation (**17**) and on the basis of the following constants: $f_1 = 25$ cyc. per sec., $f_2 = 280$ cyc. per sec., $f_c = 25$ cyc. per sec., $n_1 = n_2 = 5$, $g = 12.6$, $h = 2.2$

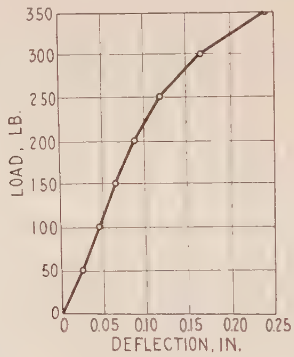

Fig. 5—Load-Deflection Curve for Support used in Test

Loads constant and slowly applied at the level of the busbar. Deflection measured at level of busbar

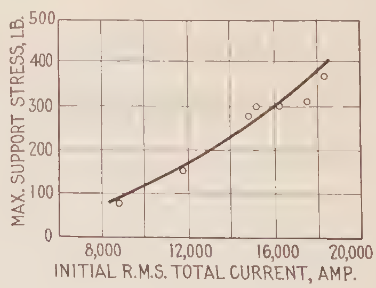

Fig. 6—Comparison of Maximum Stresses by Test and by Calculation

For conditions of Test
Points obtained by test, curve by calculation

In view of the foregoing, the support-stress calculations will be based on the following conditions:

1. Straight, uniform, parallel busbars having equidistant supports of uniform characteristics.

2. All supports, are considered equally stressed, the stresses per support being those due to the electromagnetic force for a full busbar span. A number of similar spans are assumed to be acted on by the same electromagnetic force.

3. Busbar and support deflect when stressed and have elastic properties.

4. Two-wire short circuit, the two conductors carrying equal and opposite currents.

5. Busbars at rest and unstressed before application of the short circuit.

6. The deflection of the busbars is considered to be small in comparison with the spacing between conductors; thus the electromagnetic force is regarded as independent of the deflection of the bars. The longitudinal tension in the bars is neglected.

7. The base of each support is considered to be tightly bolted to a rigid foundation.

8. The assembled bus structure is assumed to have not more than two natural frequencies.

9. In the first analysis, the motional resistance of the structural elements as well as the current decrement will be neglected. The principles of motion and of

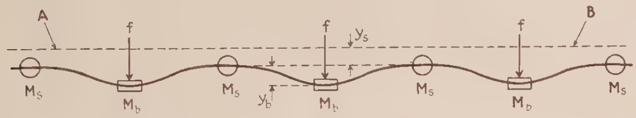

Fig. 7—Busbar-Insulator Structure with Flexible Supports

The busbar is represented with concentrated mass M_b and the support with concentrated mass M_s. Line A-B indicates the rest position of the busbar and of the supports before the electromagnetic forces are applied.

stresses can adequately and most conveniently be derived from an analysis of the motional behavior of a (hypothetical) system of negligible resistance, in the absence of current decrement. Subsequently, suitable allowance will be made for current decrement and damping.

Support Deflections and Stresses without Damping and without Current Decrement*

Since the driving electromagnetic force f per span is opposed during vibratory motion by a force due to the acceleration of the busbar mass, whose displacement at any instant is $y_b + y_s$, and by a restoring force due to the resilience of the busbar span, the following equation of busbar motion neglecting resistance is obtained, in accordance with Fig. 7.

$$M_b \left(\frac{d^2 y_b}{d t^2} + \frac{d^2 y_s}{d t^2} \right) + S_b y_b = f \qquad (3)$$

All forces are parallel and in one plane. The corresponding forces acting on the support, according to Fig. 7, define its motion as given in equation (4)† Resistance is again neglected.

$$M_s \frac{d^2 y_s}{d t^2} + S_s y_s = S_b y_b \qquad (4)$$

In order to obtain the support stress, equations (3) and (4) will be solved for y_s in terms of the structural constants and the electromagnetic force. If equation (4) is differentiated twice, with respect to time, and the equation so found is then combined with (3) and (4) for eliminating y_b and the derivatives of y_b, equation (5) the differential equation for y_s, is obtained.

$$\frac{d^4 y_s}{d t^4} + \left(\frac{S_b}{M_b} + \frac{S_s}{M_s} + \frac{S_b}{M_s} \right) \frac{d^2 y_s}{d t^2} + \frac{S_b S_s}{M_b M_s} y_s = \frac{S_b}{M_b M_s} f \qquad (5)$$

where f, the electromagnetic force, for a fully displaced sine current, without decrement, has the form

$$f = A I_m^2 (1 - \cos \omega t)^2$$

$$= 1.5 A I_m^2 \left(1 - \frac{4}{3} \cos \omega t + \frac{1}{3} \cos 2 \omega t \right) \qquad (6)$$

Then the solution for y_s from (5) and (6) is of the form

$$y_s = c_1 e^{\alpha_1 t} + c_2 e^{\alpha_2 t} + c_3 e^{\alpha_3 t} + c_4 e^{\alpha_4 t} + \frac{B F_0}{h_0^2} - \frac{\frac{4}{3} B F_0 \cos \omega t}{\omega^4 - g_0 \omega^2 + h_0^2} + \frac{\frac{1}{3} B F_0 \cos 2 \omega t}{(2 \omega)^4 - (2 \omega)^2 g_0 + h_0^2} \qquad (7)$$

In practical stress calculations the ratio $\dfrac{y_s}{y_0} = p$ is convenient to use, where y_0 is the support deflection due to a dead load equal to F_0, the electromagnetic force exerted on a busbar span by the r. m. s. initial asymmetrical short-circuit current. Hence, p multiplied by F_0 gives the support stress, and the maximum value of p is the maximum stress obtained when the initial average electromagnetic force per span is one. Accordingly, p will be called the stress factor. Thus the support stress factor, neglecting resistance and current decrement is from (7)

$$p = \frac{y_s}{y_0} = 1 + C_1 \cos q_1 t + C_2 \cos q_2 t + C' \cos \omega t + C'' \cos 2 \omega t \qquad (8)$$

where q_1 and q_2 are defined by (10), and the coefficients C_1, C_2, C' and C'' are defined by

$$C_1 = \frac{u_2^2}{u_2^2 - u_1^2}$$

*C. g. s. absolute units are employed, unless otherwise mentioned. For symbols see List appended.

†Equations similar to No. 3 and No. 4 were set up by Hort (Bibliography No. 15) for the vibrations of a system comprising a rotating machine on a flexible shaft held by two bearings which are resting on a yielding foundation.

$$\left(-1-\frac{4}{3}\frac{u_1^2}{(1-u_1^2)}+\frac{1}{3}\frac{u_1^2}{(4-u_1^2)}\right)$$

$$C_2=\frac{-u_1^2}{u_2^2-u_1^2}$$

$$\left(-1-\frac{4}{3}\frac{u_2^2}{(1-u_2^2)}+\frac{1}{3}\frac{u_2^2}{(4-u_2^2)}\right) \qquad (9)$$

$$C'=-\frac{4}{3}\frac{u_1^2}{(1-u_1^2)}\frac{u_2^2}{(1-u_2^2)}$$

$$C''=\frac{1}{3}\frac{u_1^2}{(4-u_1^2)}\frac{u_2^2}{(4-u_2^2)}$$

It is seen that all constants in equation (**8**) depend solely on the frequency ratios u_1 and u_2 (see list of symbols) so that, if the two natural frequencies

$$\left.\begin{aligned} f_1&=\frac{q_1}{2\pi}=\frac{1}{2\pi}\sqrt{\frac{1}{2}\left(g_0-\sqrt{g_0^2-4h_0^2}\right)}\\ f_2&=\frac{q_2}{2\pi}=\frac{1}{2\pi}\sqrt{\frac{1}{2}\left(g_0+\sqrt{g_0^2-4h_0^2}\right)}\end{aligned}\right\} \qquad (10)$$

are known, the stress factor is readily calculated by (**8**) and (**9**), neglecting resistance and current decrement.

Effects of Current Decrement and of Damping at Non-Resonance

The decreasing electromagnetic force due to short-circuit currents is expressed in the form:

$$f=F_0\left(\frac{2}{3}e^{-2gt}+\frac{1}{3}e^{-2ht}-\frac{4}{3}e^{(-g-h)t}\cos\omega t+\frac{1}{3}e^{-2ht}\cos 2\omega t\right) \qquad (11)$$

g and h being the current decrement constants.

An approximate working formula, taking into account current decrement and damping, (derived from (**8**) and (**10**)) for estimating maximum short-circuit stresses in bus supports at non-resonance is then the following:

$$p=\frac{y_s}{y_0}=\frac{2}{3}e^{-2gt}+\frac{1}{3}e^{-2ht}+C_1e^{-0.5\alpha' t}\cos q_1t+C_2e^{-0.5\alpha'' t}\cos q_2t+C'e^{(-g-h)t}\cos\omega t+C''e^{-2ht}\cos 2\omega t \qquad (12)$$

where the constants C are those of (**9**). Equation (**12**) is not applicable to resonant cases in the form given. The practical use of (**12**) calls for the following data:

- the two natural frequencies f_1 and f_2
- the current frequency f_c
- the current decrement constants g and h
- the motional resistance decrement constants α' and α''

Stresses at Resonance

Definition of Resonance. Resonance will be defined as the condition of cyclically increasing stress amplitudes (or vibration amplitudes) occurring when a force of a frequency equal to one of the natural frequencies (f_1 and f_2) is impressed on the bus structure. The four cases of resonance for bus structures are:

$$u_1=1 \qquad (13a)$$
$$u_2=1 \qquad (13b)$$
$$u_1=2 \qquad (13c)$$
$$u_2=2 \qquad (13d)$$

Condition for Maximum Stresses. It is well known that, strictly speaking, the maximum deflection due to sustained forced vibrations occurs at an impressed frequency slightly different from the resonant frequency above defined*, the difference depending on the damping constant. The magnitude of the diffierence, however, is less than one per cent in frequency and less than one per cent in deflection, for the constants coming into question in bus structures. For practical calculations, therefore, the differences mentioned may be ignored.

Resonance without Resistance and without Current Decrement. The four cases of resonance defined in (**13**) are fundamentally similar to one another. As an illustration of the theory, the case of $u_1=1$ will be worked out, which is the case of resonance between ω and q_1 in equation (**8**).

Mathematically, we may determine the form of the resonant component of stress factor for the case when ω and q_1 become equal, by determining from equation (**8**)

$$\lim_{q_1\doteq\omega}\left[C_1\cos q_1t+C'\cos\omega t\right]=\frac{y_r'}{y_0} \qquad (14)$$

where y_r' is the component of support deflection at resonant angular velocity $\omega=q_1$. By evaluating the indeterminate form contained in equation (**14**), in the customary manner, it is found that

$$\frac{y_r'}{y_0}=\frac{4u_2^2(5-2u_2^2)}{9(1-u_2^2)^2}\cos\omega t+\frac{2u_2^2}{3(1-u_2^2)}\omega t\sin\omega t \qquad (15)$$

In equation (**15**) the sine term, containing the factor ωt, is the one expressing the progressive increase of vibration amplitude characteristic of all cases of resonance. The expression shows that the amplitude of the resonant component of stress increases at the following rate:

$$\frac{2\pi u_2^2}{3(1-u_2^2)}F_0 \text{ for each half cycle}$$

indicating that the increase per half cycle of the support stress component at resonant frequency is equal to that

*See Bibliography No. 17, p. 463; also Bibliography No. 26, pp. 41, 42.

which would be obtained if the support were impelled directly by a harmonic driving force of the amplitude

$$\frac{4}{3}\left(\frac{u_2^2}{1-u_2^2}\right)F_0 \qquad (16)$$

where the ratio in brackets is a modulating ratio applied to the amplitude of the resonant component of the impressed electromagnetic force. The expression (16) may then be regarded as the amplitude of an equivalent driving force impelling the support.

For resonance between q_2 and ω, an expression analogous to (16) is obtained with u_1 substituted for u_2.

Since it is desirable to keep the magnitude of the resonant stress as low as possible, the non-resonant natural frequency should be as far from resonance as possible, and preferably of lower value than the resonant natural frequency.

Resonant Stresses Including Resistance and Current Decrement. The stress factor at resonance, including allowance for resistance and current decrements is in accordance with (11), (14), (15) and (16).

$$p = \frac{y_s}{y_0} = \frac{2}{3}e^{-2gt} + \frac{1}{3}e^{-2ht} + C_2 e^{-\frac{1}{2}\alpha'' t}\cos q_2 t$$

$$+ C'' e^{-2ht}\cos 2\omega t + \frac{y_r'}{y_0} \qquad (17)$$

where

$$\frac{y_r'}{y_0} = \frac{4}{3}\frac{u_2^2}{(1-u_2^2)}\cdot\frac{(1-e^{-(g+h)t})}{(g+h)\,t}$$

$$\left[n_1(1-e^{-\frac{\alpha' t}{2}})\sin\omega t + \frac{5-2u_2^2}{3(1-u_2^2)}e^{\frac{\alpha' t}{2}}\cos\omega t\right] \qquad (18)$$

and C_2 and C'' are the factors defined in (9). Expressions (17) and (18) apply, of course, to resonance between q_1 and ω only, the expressions for the other three cases of resonance being similar.

Damping and Decrement Constants

The effect of damping on resonant stresses is taken into account by the use of the "sharpness of resonance" defined by n_1 and n_2 (see list of symbols). Obviously, an increased amount of damping gives a reduced value of resonance sharpness. Tests performed on a variety of bus structures employing copper bars and porcelain insulators gave $n_1 = n_2 = 5$, on an average. This value was used in the preparation of the stress curve of Fig. 1. Other types of bus structures require, of course, different values of resonance sharpness, in some cases well above 5.

In (11), exponential rates of current decrement were assumed, different rates being applied to the direct component and to the alternating component. For approximate calculations of maximum short-circuit stresses in busbars, g and h in (11) may be given the values 12.6 and 2.2, respectively, provided 1, short-circuit currents with a maximum amount of initial displacement are considered; 2, the system reactance is within the range from, say five per cent to 30 per cent; and 3, the time of the maximum stress is not later than, say, 0.1 or 0.15 sec. after the beginning of the short-circuit. Tests have shown that the maximum in exceptional cases only, occurs later than 0.15 sec. after the beginning of the short circuit.

Symbols

α', α'' resistance decrement constants in free vibrations

$\alpha_1, \alpha_2, \alpha_3, \alpha_4$ roots of equation $\alpha^4 + g_0\alpha^2 + h_0^2 = 0$

A electromagnetic force per busbar span per unit current

a (in.) dimension of individual busbar lamination, measured in the direction of its deflection due to short-circuit electromagnetic force.

B substitution for $\frac{S_b}{M_b M_s}$

b (in.) dimension of individual busbar lamination, measured in the direction perpendicular to its deflection due to short-circuit electromagnetic forces.

c_1, c_2, c_3, c_4 constants of integration.

C_1, C_2, C', C'' amplituees of harmonic components of stress factor for zero resistance and no decrement; see (8) and (9).

$e = 2.718$ .. ..

l length of busbar span, measured between centers of supports.

F_0 electromagnetic force per span for a current of I_0 per conductor $= A\,I_0^2 = 1.5\,A\,I_m^2$.

f instantaneous value of electromagnetic force per busbar span.

f_c (cyc. per sec.) frequency of current.

f_1 (cyc. per sec.) lower natural frequency of bus structure.

f_2 (cyc. per sec.) higher natural frequency of bus structure.

$g_0 = \frac{S_b}{M_b} + \frac{S_s}{M_s} + \frac{S_b}{M_s}$

g decrement constant of d-c. component of short-circuit current

$h_0^2 = \frac{S_b}{M_b}\frac{S_s}{M_s}$

h decrement constant of a-c. component of short-circuit current.

k shape correction factor for the calculation of electromagnetic force.

I_0 r. m. s. value of initial asymmetrical short-circuit current at time $t = 0$; also $I_0 = 1.225\,I_m$.

I_m maximum value of a-c. component of short-circuit current at time $t = 0$.

M_b equivalent busbar mass, concentrated at the center of the busbar span.

M_s equivalent support mass considered concentrated at center line of busbar over the center of the insulator; M_s includes the part of the busbar mass which follows with the support in its motion.

n_1, n_2 sharpness of resonance, defined by

$$n_1 = \frac{q_1}{\alpha'}$$

$$n_2 = \frac{q_2}{\alpha''}$$

ω $= 2\pi f_c$ (radians per sec.)

P (lb. per support) maximum support stress

p stress factor for calculation of support stress

q_1, q_2 angular velocities of natural frequency vibrations, defined by (**10**); q_1 is smaller than q_2

S_b stiffness of equivalent busbar in direction parallel to deflection due to electromagnetic force

S_s stiffness of support

s center spacing of parallel busbars

t (sec.) time, measured from beginning of short circuit

$u_1 = \dfrac{q_1}{\omega}$ = ratio of lower natural frequency to current frequency

$u_2 = \dfrac{q_2}{\omega}$ = ratio of higher natural frequency to current frequency

y_b deflection of equivalent busbar span relative to supports.

y_s deflection of support in a direction parallel to the direction of the electromagnetic force

y_0 average support deflection $= \dfrac{B\,F_0}{h_0^2} = \dfrac{F_0}{S_s}$

y_r' component of support deflection at resonant angular velocity $q_1 = \omega$.

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No less than 17.6 per cent of city night traffic accidents, according to a survey of 31,475 accidents in the police records of 32 cities in this country, are attributable to poor street lighting.

Automobile accidents alone, it is estimated by Dr. Crum, Statistician of the Prudential Life Insurance Company, are the cause of an annual personal property loss of one billion dollars.

Development and Characteristics of a 1,000,000-Volt Cascade Transformer at California Institute of Technology

BY ROYAL W. SORENSEN[1]

Fellow, A. I. E. E.

***Synopsis.**—This paper is presented to describe the cascade connection for transformers, and show the standard characteristics of such equipment, but it does not give building-plans for the 1,000,000-volt laboratory, as they have been presented in other publications.*

HIGH-voltage power transmission began in California. Economic laws of demand and supply have vindicated the faith of those electrical pioneers to whom we do special honor at this convention; in no other part of the world is the transmission of power over great distances so highly developed.

The many problems incident to such a development may be arranged in two groups, one having to do with the manufacture of apparatus, and the other having to do with methods of operation.

The supply of raw materials and living habits of craftsmen establish factory locations. The management of factories manufacturing electrical apparatus have been very sagacious in establishing experimental and research laboratories in which problems of both groups have been solved, and although these laboratories have been of inestimable value to the operating companies, they are so far from the Pacific Coast Power Companies as to make their full use by engineers of these companies very difficult.

The absence of such laboratories near at hand has often caused Pacific Coast engineers to conduct in the field, with the greatest of difficulty, tests which could be made in whole or in part very quickly in a properly equipped laboratory, or to make long trips to factories to use the factory laboratories. This situation was particularly acute when the preliminary work for the 220 kv. lines, just put into operation last year, was being done.

Future development is almost certain to warrant the use of voltages higher than 220 kv. In anticipation of such development, and to facilitate the solution of operating problems arising as a result of the use of the 220 kv. transmission with its large secondary distribution networks, the Southern California Edison Company has established at California Institute of Technology a high voltage research laboratory.

The location is strategic because it is convenient for engineers of the Edison Company, and it associates with the laboratory all the equipment and personnel of the Norman Bridge Laboratory of Physics under the direction of Dr. Millikan, and the department of electrical engineering of the Institute. Also it is economic because there is available a certain amount of student energy which can be expended in investigating problems of unknown economic value, thus avoiding the necessity of having the Utility Companies establish and maintain a personnel specially trained for this type of work.

This laboratory is of interest because it will be used by Dr. Millikan and his associates for work carried on by them in determining the structure of matter and other problems in physics, as well as for engineering problems. Also it is the first laboratory projected for the production of 1,000,000 volts from line to ground, and is the first installation to use cascade or chain connected transformers. This connection was originated by the author first as an interesting transformer combination, and then applied to this problem at a time when there appeared no other way of obtaining a potential of 1,000,000 volts from line to ground.

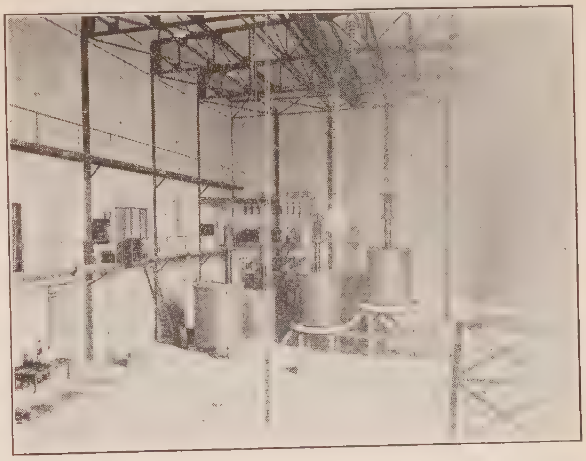

FIG. 1—FOUR 250-KV-A., 250,000-VOLT, 50-CYCLE WESTINGHOUSE TRANSFORMERS, INSTALLED ON STEEL FRAMES SUPPORTED BY PORCELAIN INSULATORS

The fact that several other installations using this connection are now being constructed appears to warrant its use, though other ways for producing 1,000,000 volts line to ground have been developed.

In this particular installation four 250 kv-a., 250,000-volt 50-cycle Westinghouse transformers, installed on steel frames supported by porcelain insulators as shown in Fig. 1, are used.

An inspection of what is inside one of the tanks discloses a core type transformer with the regular primary and secondary windings, and an additional winding designated as the exciter winding. Fig. 2 shows the assembly of core, coils, static shields enclosing the core and coils, and the insulation barriers between the shields and the tank.

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Presented at the Pacific Coast Convention, October 14-19, 1924.

The primary is divided into two cylindrical sections, one on each leg of the core. Over each of these sections and concentric with them are concentric micarta tubes of varying length, the inner ones being practically the full length of the core, whereas the outer ones are only a portion of this length. The tubes between the inner and outer ones are graded in length between these

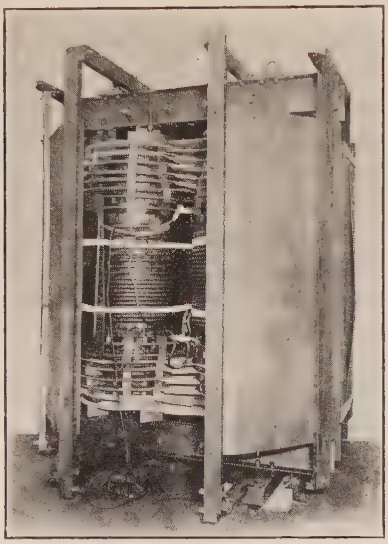

Fig. 2—Assembly of Core, Coils, Static Shields Enclosing Core and Coils, with Insulation Barriers Between Shields and Tank

two limits. On each of these tubes, with the exception of the two outer ones on each leg, is a section of the secondary or high voltage winding, these windings being connected in series, the connections alternating

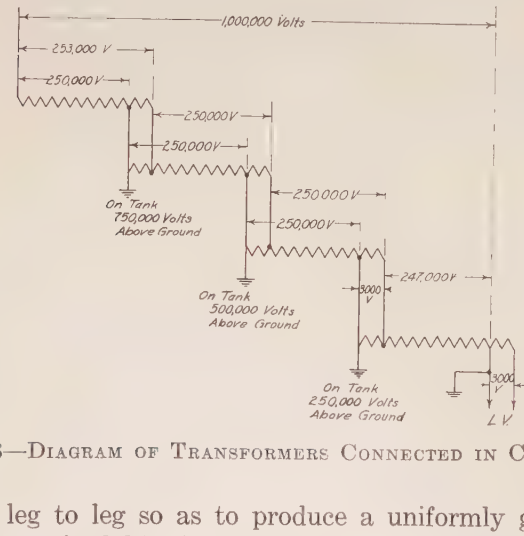

Fig. 3—Diagram of Transformers Connected in Cascade

from leg to leg so as to produce a uniformly graded electrostatic field. The two outer cylinders on each leg are reserved for the exciter winding, which is divided into two parts, one on each leg. The two parts are connected in multiple.

The primary is wound for $\frac{3000}{6000}$ volts, the secondary for 247,000 volts, and the exciter winding for 3000 volts.

When the transformers are connected in cascade the three windings of each transformer are connected in series, thus forming an auto transformer having three sections, the several transformers being connected together as shown diagrammatically in Fig. 3.

The primary leads are all brought out according to standard practise for series-parallel connections. The grounded secondary lead is brought outside the tank to an ammeter jack and thence to a ground on the tank.

The high voltage terminal of the secondary is tapped off at the junction of the secondary and exciting windings and brought out through a tube which forms the

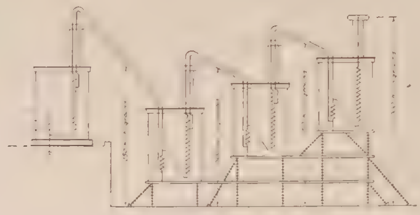

Fig. 4

lead for the high potential end of the exciter winding. This tap lead and the 250,000 volt lead are insulated from each other by a small cylinder of micarta. The 250,000 lead is in all other respects a standard condenser lead for a transformer of this voltage.

In addition to these windings each transformer is provided with a two section $\frac{150}{300}$ volt voltmeter winding.

Fig. 4 illustrates the assembly connection for 1,000,000 volts, one end grounded.

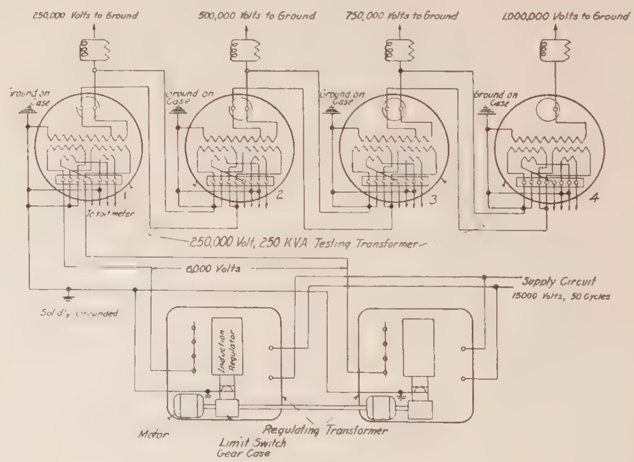

Fig. 5

Fig. 5 shows the complete wiring diagram for this connection.

The regulating transformers shown in this diagram are an ingenious combination of transformer stepping down from 15,000 to 3000 volts and a small induction regulator. The 3000 volt winding has taps which are so arranged that by means of the small regulator, sup-

plemented by a third winding and a special current transformer, the secondary voltage of the regulating transformer may be gradually and smoothly changed from zero to 3000 volts.

These regulators and the switches are controlled from two control desks located one on the first observation gallery and one on the main floor.

The units may be connected for various combinations, both single and three phase, and controlled as a whole from either desk, or they may be separated and operated from different desks each independent of the other.

The natural development stages for such a project are financing, engineering, construction, erection, testing, and operation.

The financing, contrary to usual practice, was not difficult because of the broad outlook of the Southern California Edison Company officials and engineers and the excellent cooperation of the Westinghouse Electric and Manufacturing Company.

The engineering presented some problems of education because of lack of previous similar connections and the apparent inclination on the part of manufacturing companies to discourage a college laboratory from having such equipment.

In particular, there was a strongly expressed opposition to the cascade connection on the basis of large phase displacement and consequent uncontrollable terminal voltage as compared to the voltage of each unit. Preliminary tests made by the author, using standard lighting transformers up to twelve in number, gave no indication of such trouble, and subsequent tests made on the completed equipment also show this factor to be inconsequential.

The construction presented no new difficult problems because each unit is constructed as a 250,000 volt unit, many of which have been built. Special care, however, was taken to keep the reactance between the primary and the exciter windings, which must be well insulated from each other, as low as possible consistent with the safety of insulation desired.

The erection presented only one difficult problem, viz. the securing of a reasonable priced insulator strong enough to support the weights involved, and guard against lateral forces which might at sometime upset the structure. In fact so difficult was it to secure such insulators that a reluctant decision to use stands of redwood timbers was made.

This decision seemed at the time reasonable because tests of many redwood samples, together with long experience insulating various circuits, including high frequency Poulsen arc circuits, with redwood, indicated that it would be satisfactory.

After the stands were made, using 6-in. by 6-in. timbers all of which were seasoned by long storage, unit No. 2 was mounted thereon and an attempt made to bring up the voltage. When the tank of unit 2 was up to a potential of about 75,000 volts above ground a bit of smoke was noticed at the foot of one of the four legs of the 9-foot-high stand upon which the transformer rested. This was a disconcerting surprise because a stand made to 1/10 scale had many times stood a higher potential without any sign of distress. Fearing some disaster to the transformer, should the stand collapse, some timbers like those in the stand were secured and placed under test at 200,000 to 250,000 volts. These timbers when subjected to this voltage, supplied by a 250-kv-a. transformer, would hold up for 20 to 30 minutes, or until we felt almost certain of having solved the problem. After this time had elapsed there would suddenly appear at the electrodes on some of the timbers, and at spots along the timbers, little jets of steam. These were in practically all cases followed very quickly by explosions violent enough to split the timbers open from end to end. Following this discovery 4-in. by 4-in. sample timbers of oak, hickory, redwood, maple, ash and other woods were thoroughly boiled in paraffine and subjected to test.

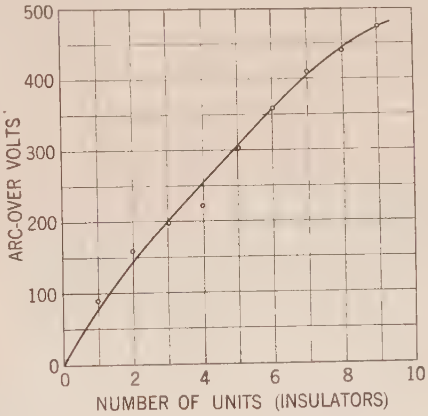

Fig. 6

Pieces seven feet long stood 500,000 volts without harm, but these same samples, when quartered, showed large internal cracks due possibly to driving off the moisture during the impregnating process.

Simultaneously with these additional experiments with wood many tests were made on glass plates, micarta sheets, etc., and a further search made for a suitable porcelain insulator. All materials tried, other than porcelain proved inadequate where large power was involved, but fortunately the later search for a suitable insulator disclosed a very special Jeffery DeWitt insulator unit, which could readily be assembled in stacks of any desired number. Compression tests on these units with three in a column indicated a compression of approximately 150,000 lbs. as necessary to cause mechanical cracking or breaking. In as much as each transformer weighs 45,000 lbs. complete, and four columns of units are used to support it, an ample factor of safety is assured and the structure shown in Fig. 1 was designed and installed. This being successful, the mechanical insulation problems were solved.

Testing. Insulator stacks: The insulators used for constructing the racks when tested dry singly and in

column with one end standing upon the floor and no shielding at the top of the stack gave results as shown by curve in Fig. 6 or data of Table I.

Shielding. Terminals of Units 1 and 2 can be brought up to 250 kv. or 500 kv. above ground without any undesirable corona. But Units 3 and 4 require additional shielding over that provided by the high voltage bushing of the unit. This was accomplished on Unit 3 by by the addition of a six inch ball on the tap lead terminal and a torus about 6 in. in cross section around the top of the choke coil, level with the tap lead terminal. Unit 4 has the tap lead left out but it is necessary to place above the choke coil a large torus made of hoop iron, covered with tinfoil to obtain a smooth surface.

TABLE I

No. Units in stack	Kilovolts to Arc over Stack
1	90
2	150
3	200
4	245
5	310
6	360
7	420
8	460
9	490

The regulating transformers were tested only for insulation, ratio, polarity, and operation. In the operation test they have functioned well, as they give excellent voltage control from zero to 3000 volts on the secondary, with 15,000 volts on the primary, without any evidence of irregularity either in rate of control or smoothness of voltage change.

The four transformers have been tested individually and in cascade for ratio, polarity, core loss, impedance, charging current values, etc.

A ratio test at low voltages followed by one at voltages up to normal on the individual units showed at no load true ratio of turns readings on the meters for primary, secondary, volt coils, and exciter windings, the high tension voltage being determined by a sphere gap.

TABLE II

Prim. Volts	Ratio, Coil Volts, Unit No 1, average several readings	Gap Setting Inches	Kilovolts Indicated by Gap Setting	Volt Coil Reading Multiplied by Secondary — Volt Coil × 1000
2400	242	106	1000	801
2265	227	96	900	753
2080	208	90	850	694
1880	188	81.75	770	627
1730	173	69.5	650	577
1420	142	57.25	540	473
1120	112	45.75	430	374
950	95	38	370	316
560	56	23.25	230	186

On ratio test at no load with all four units connected in cascade results shown in Table II and Curve of Fig. 7 were obtained. The secondary voltage in this case being measured by means of needle gaps.

As is always the case there is a boosting of voltage in the secondary of such high voltage step up transformer, but this is not excessive as compared to the

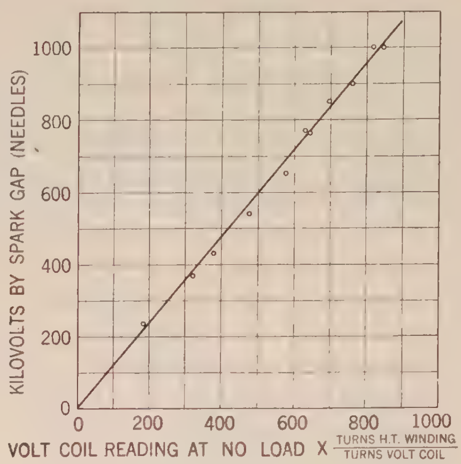

Fig. 7

results to be obtained with any type of transformer for so high a voltage.

A disappointing feature has been the failure of the volt coil to show a voltage more nearly in proportion to the secondary voltage rather than so nearly in accord with the primary voltage. This fact is made doubly disappointing because with the cascade connection for a voltage this high most of the boosting of voltage is in

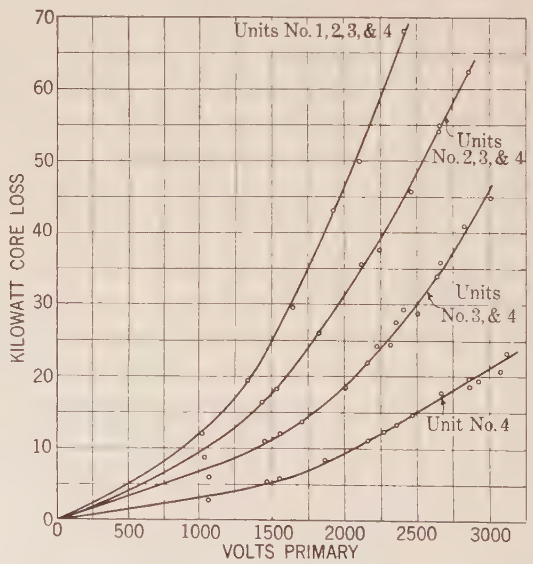

Fig. 8—Core Loss Curves at 49½ Cycles 1,000,000-Volt Cascade Transformer at California Institute of Technology

the grounded unit as evidenced by check tests up to 500,000 volts in which the ratio between the reading on the volt coil of unit 1 and the high tension terminal voltage of unit 2 is just twice the ratio between the reading on volt coil of unit 1 and the high tension terminal voltage of unit 4.

Core Loss Tests. Core loss tests were made on each unit at 49.5 cycles, the energy being supplied directly by the incoming power circuit.

The average values of these readings were:

Core loss at 3000 volts primary = 214,000 watts

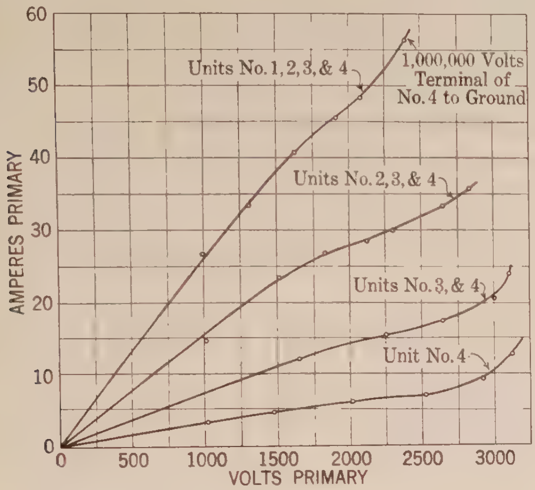

Fig. 9—Exciting Current Curves

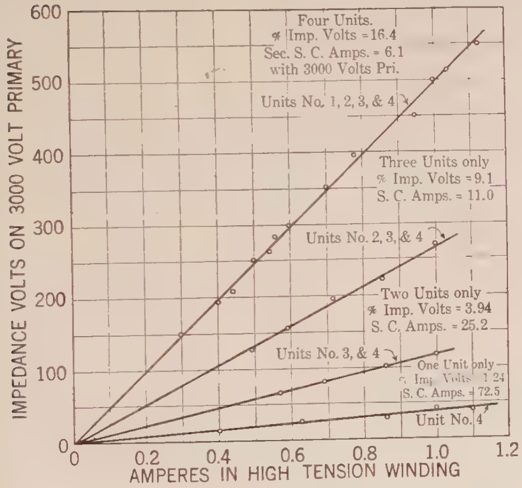

Fig. 10—Impedance Curves for 1,000,000-Volt Cascade Transformer at California Institute of Technology, with High Voltage Winding, Short-Circuited

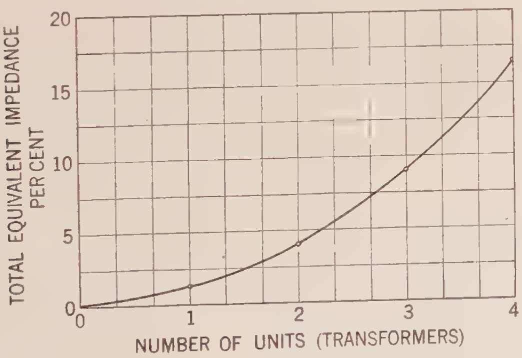

Fig. 11

Exciting current at 3000 volts primary = 14.5 per cent of 250 kv-a. rating

Core loss tests were also made with two units, three units, and four units respectively connected in cascade. The results of these tests are shown in curves of Fig. 8.

It will be seen from these tests that at the lower voltages the core loss of any combination of units closely approximates the sum of the core losses of the several units just as one would expect. At the higher voltages the total apparent core loss is greater than the

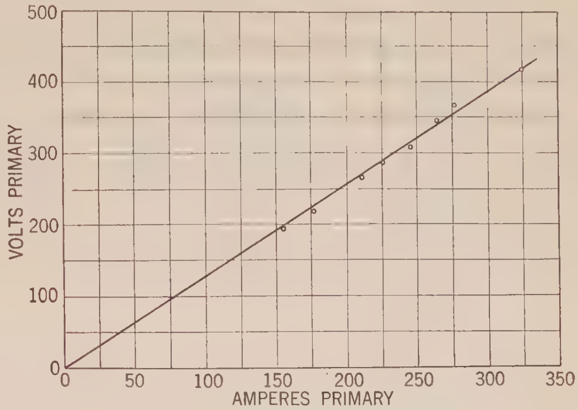

Fig. 12—Impedance Curves. Exciter Winding Short-Circuited. Volts Applied to Primary

sum of the several losses by an amount equal to the copper losses in the exciter windings and the primaries.

Fig. 9 shows the exciting current curves for 1, 2, 3 and 4 units. When more than one unit is used the units are connected in cascade.

Impedance Test. Fig. 10 shows impedance curves

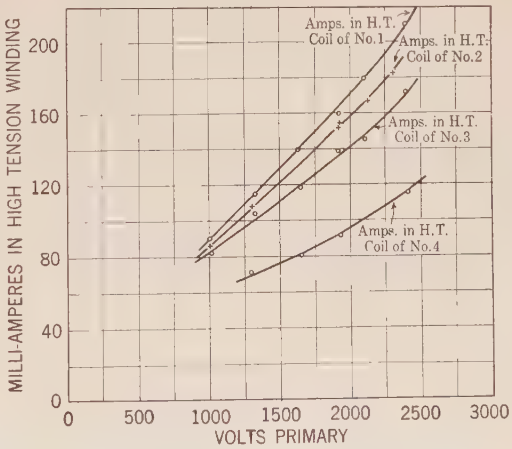

Fig. 13—Current in High Tension Windings on Core Loss Test with Four Units On

for 1, 2, 3 and 4 units, the curves being plotted with current in the high voltage winding as abscissae and impedance volts as ordinates. Fig. 11 shows a plot with the number of transformer units as abscissae and per cent impedance volts at normal secondary current as ordinates. It will be observed that the average impedance volt of any one of the four transformers used individually is 1.25 per cent. This low impedance gives very little protection to the transformer on short circuit, whereas with all four units in cascade the

equivalent impedance volts at full load high tension current is 16.4 per cent, a much more satisfactory value for a testing transformer.

Fig. 12 shows the relation between current in the primary winding and the impedance volts across that winding when the exciter winding only is short circuited. With a primary current of 333 amperes, normal for a 1000 kv-a. load, the impedance volts are for this connection 14.1 per cent. This is also practically the value of the reactance in per cent, the resistance drop for this test being less than two per cent.

Charging Current. In planning for a connection of this type there was considerable conjecture as to the current required to charge units 2, 3, and 4 which are insulated from ground. Fig. 13 shows curves of current in the high voltage windings of the several units. These curves are plotted with miliamperes as abscissae and primary volts as ordinates.

Following these tests a set of tests was made with 3, 2, and 1 units respectively used to generate voltage and charge the tank above to its normal operating potential. That is with units 1, 2 and 3, operating cascade, unit 4 being connected to terminal of unit 3 but not excited, readings of currents in high voltage windings of these units were taken for various primary voltages. A similar set of readings with unit 4 disconnected. The differences between these readings were those shown in the curves of Fig. 13 and are the charging currents required to charge the tanks of units 2, 3 and 4 respectively.

Operation. The newness of this equipment precludes any record of operation except to state that it makes a very flexible equipment which has been satisfactory under all conditions for which it has been used.

Not the least of the desirable features of the cascade connection is the possibility of having separate units of 250 or 500 kv. at 250,000 and 500,000 volts respectively, or of connecting the high voltage windings of three units in a star, thus obtaining 433,000 volts three phase.

Many other combinations of which the following are illustrative, may be obtained: 1,000,000 volts between terminals, center grounded; 500,000 volt step up down, single phase system with one end or center grounded as desired.

Acknowledgment. The bronze tablet placed just within the west entrance of the laboratory as an acknowledgment to the Southern California Edison Company, without whom such a laboratory would not have been possible.

Metallic Polar-Duplex Telegraph System for Long Small-Gage Cables

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Synopsis.—*In connection with carrying out the toll-cable program of the Bell System, a metallic-circuit polar-duplex telegraph system was developed. The metallic-return type of circuit lends itself readily to the cable conditions, its freedom from interference allowing the use of low potentials and currents so that the telegraph may be superposed on telephone circuits. The new system represents an unusual refinement in d-c. telegraph circuits, the operating current being of the same order of magnitude as that of the telephone circuits on which the telegraph is superposed.*

The metallic system is suitable for providing circuits up to 1000 miles or more in length, the grade of service being better than that usually obtained from ground-return circuits on open-wire lines for such distances. About 55,000 miles of this type of telegraph circuit are in service at present.

Introduction

THERE has been developed recently by the Bell System a low-current metallic telegraph system, of the polar-duplex type, which is suitable for superposition on telephone circuits in long small-gage cables. In certain sections where long-distance toll traffic is heavy, it becomes desirable, from the standpoints of economy and continuity of service, to employ such cables to replace existing open-wire lines and to provide for future growth. The new telegraph system is being applied on a considerable scale in connection with the toll cable system, the general features and telephone arrangements of which have been described in previous papers.[3] The present paper outlines the general features of the metallic telegraph system and the method of superposing telegraph circuits of this type upon "two-wire" and "four-wire" telephone circuits in small-gage cables.

The metallic-return or two-wire type of telegraph circuit was chosen in preference to the ground-return type because it appeared to offer a more straightfor-

1. Bell Telephone Laboratories, Inc.

2. American Telephone and Telegraph Co.

Abridgment of paper presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 9-12, 1925. Complete copies available upon application at headquarters.

3. Philadelphia-Pittsburgh Section of the New York-Chicago Cable, J. J. Pilliod, JOURNAL A. I. E. E., Aug. 1922, p. 446.

Telephone Transmission Over Long Cable Circuits, A. B. Clark, JOURNAL A. I. E. E., Jan. 1923, p. 1.

Telephone Equipment for Long Cable Circuits, C. S. Demarest, JOURNAL A. I. E. E., Nov. 1923, p. 1159.

ward solution of the technical problem and to be more economical, sufficient cable conductors being available as a result of the telephone requirements. On a long telephone circuit in a small-gage cable it is necessary to employ a number of repeaters with comparatively large amplification and also to insert loading coils in the line at short intervals. As a result, the interference from superposed telegraph would be excessive unless the telegraph voltages and currents were kept far below the values ordinarily employed for ground-return telegraph. To allow the use of small currents and poten-

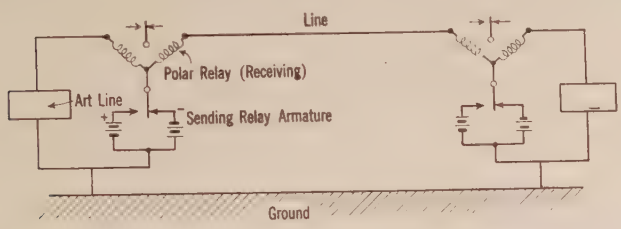


Fig. 1—Differential Duplex on Grounded Circuit

tials with ground-return telegraph would require the development of arrangements for neutralizing difference in earth potential and inductive interference from telegraph circuits in the same cable as well as from power circuits. It will be evident that a metallic telegraph circuit possesses certain transmission advantages over a ground-return telegraph circuit in the same way that a metallic telephone circuit possesses advantages over a ground-return telephone circuit.

This development resulted in a telegraph system which in some ways is unique in its refinement. The telegraph line currents are of the same order of magnitude as those of the telephone circuits which use the same wires. Although cable is fundamentally much less favorable to telegraph transmission than open wire, one mile of small-gage cable having as much effect as many miles of open wire, the present system

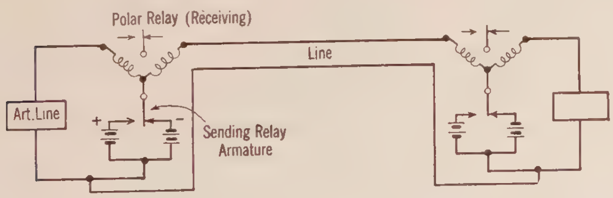


Fig. 2—Differential Duplex on Metallic Circuit

affords satisfactory operation on each pair of the cable for distances up to 1000 miles (1600 km.) or more.

Two improved forms of mounting are employed; in one of these a repeater is built as a single self-contained unit and in the other a repeater consists of several units mounted on upright I-beams. The relays are quiet in operation and sounders are normally made inoperative mechanically as they are seldom used. Altogether, a metallic repeater office bears little resemblance to the older type of office with apparatus mounted on tables and hundreds of sounders in operation.

Principles of Operation

In describing the general principles upon which the present telegraph system operates, it will be convenient to evolve it from the familiar ground-return polar-duplex system, the essential features of which are illus-

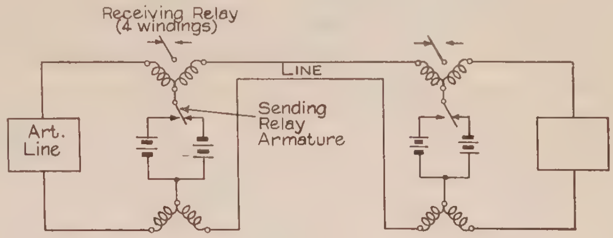


Fig. 3—Symmetrical Differential Duplex on Metallic Circuit

trated in Fig. 1. It will be seen that at each end of the line circuit there are provided a transmitter and a receiving relay. The operation of the transmitter sends current into the line and the artificial line, one polarity being used for "marking" and the other for "spacing."

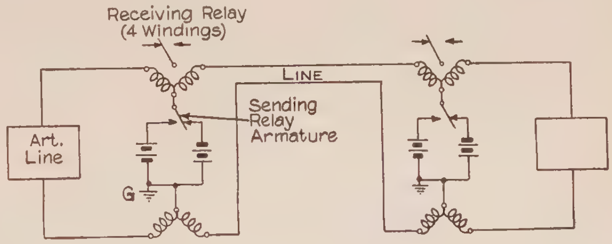


Fig. 4—Metallic Duplex Circuit—Single Commutation

If the artificial line has the same impedance as the real line, there will be no effect upon the receiving relay, since the latter is connected differentially. Currents received from the transmitter at the distant station will, however, cause the receiving relay to operate.

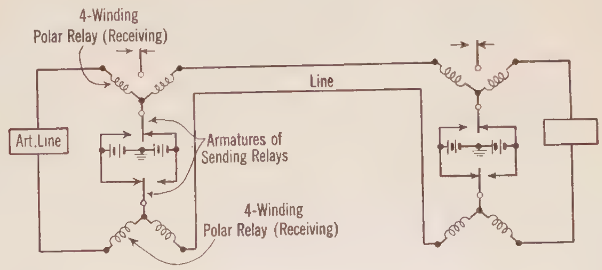


Fig. 5—Metallic Duplex Circuit—Double Commutation

The arrangement, therefore, makes it possible to send telegraph signals in either direction, or in both directions simultaneously.

In Fig. 2 the ground-return is replaced by a second line wire so that the circuit is now a metallic circuit.

Fig. 3 differs from Fig. 2 only in that each receiving

relay has its windings divided into four parts instead of two, making the circuit symmetrical.

For actual operation involving the working of a number of circuits in a given office from the same set of batteries, it is desirable to make a connection to ground at each station at the point G as shown in Fig. 4. These connections stabilize the system and facilitate the clearing of accidental grounds. Although this results in unbalancing the currents in the circuit, there is substantially no effective change in the metallic or two-wire operating currents if the line and apparatus are

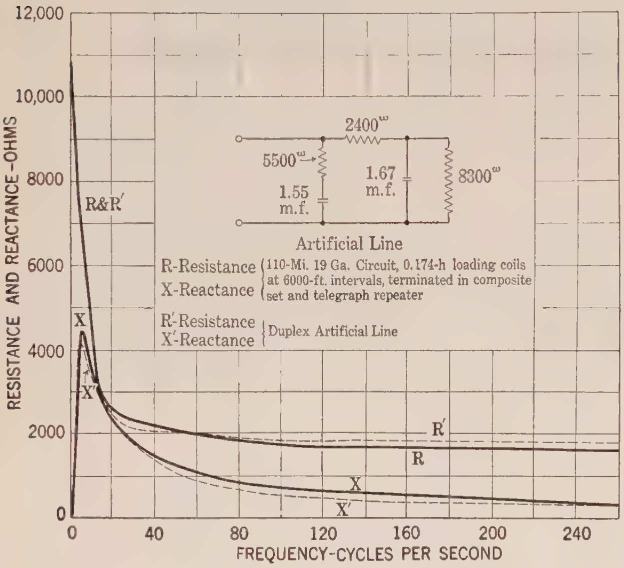


Fig. 8—Impedance of Line and Artificial Line

well balanced, and this arrangement has the essential characteristics of an actual metallic telegraph circuit. It may be helpful, however, to consider that the upper wire is employed for the transmission of signals and the lower wire is used to carry only neutralizing current to offset the effect of currents in the upper wire which are due to earth-potential differences and voltages to ground caused by induction from power or telegraph circuits. Since each pair in the cable is closely balanced, encloses a small loop, and is frequently transposed by twisting, it will be apparent that the currents due to interference are practically equal in the two wires, flowing in the same geographical direction and therefore do not affect the balanced relays.

Fig. 5 shows another arrangement of a metallic telegraph circuit in which the transmitter comprises two tongues, reversing the connections to a single battery instead of switching between two different batteries as in the case of Fig. 4. The ground connection at the midpoint of the battery at each station is for the purpose of stabilizing the system and facilitating the clearing of trouble.

Circuits of the type shown in Fig. 5 were first developed and put into extensive use in preference to the type shown in Fig. 4, largely for the reason that it was not at first practicable to obtain sufficiently close balance of relay windings. With improved relays, telegraph repeaters have been designed to operate on the basis of Fig. 4, effecting certain economies. These two arrangements, which are known respectively, as "double commutation" and "single commutation," may be operated one against the other in a telegraph repeater section.

The local circuits of the repeaters are arranged so that they may be conveniently set up either for simultaneous operation in both directions (known as full-duplex) or for operation in only one direction at a time (called half-duplex), the latter giving the same communication facilities as a simple open-and-close Morse telegraph circuit.

General Features

As in the case of other telegraph systems it is necessary to subdivide a long circuit into sections by means of repeaters to avoid the use of excessive potentials and to limit the distortion of signals. For repetition between two metallic cable circuits a simple arrangement called a "through repeater" is employed. The equipment used at the end of a metallic telegraph circuit is known as a "terminal repeater."

The metallic polar-duplex system operates with a potential of 34 volts, requiring one 34-volt battery for double-commutation and two such batteries for single-commutation. Where both are used in the same office, one of the single-commutation batteries may be used for double-commutation, this being equivalent to the regular arrangement with a ground potential of 17 volts

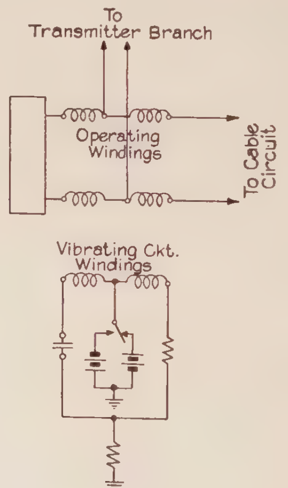


Fig. 9—Vibrating Circuit

in addition. The batteries are ordinarily "floated." Tungar rectifiers are generally used, without causing any noise in the telephone circuits.

The telegraph current in the cable circuit, with the batteries at the two ends aiding, is from about 3 to 15 milliamperes depending on the resistance of the line circuits. With the batteries opposing, the current is, of course, practically zero.

The small-gage cables are made up of No. 16 and

No. 19 B. & S. gage (1.29 and 0.91 mm. respectively) copper conductors, and the metallic telegraph system may be operated over conductors of either gage, or over the derived phantom circuits when the latter are not in use for telephone service. The maximum distance between two consecutive repeaters is about 120 miles (195 km.) on 19-gage, composited pairs, or 160 miles (260 km.) on 16-gage. For non-composited circuits the corresponding distances are about 140 miles (225 km.) and 190 miles (305 km.) respectively. The average telegraph repeater section is about 100 miles (160 km.) in length as a result of the telephone requirements in connection with locating repeater stations. In come cases the telegraph is operated over non-loaded circuits, such conductors being available before loading coils have been applied to all wires of the cable. The telegraph transmission is practically the same on non-loaded and loaded circuits.

Curves of resistance and reactance versus frequency are shown in Fig. 8, for a representative metallic line section and the corresponding artificial line. It will be noted that there are large variations in these impedance components in the frequency range from zero to about 30 cycles per second, and they tend to become constant as the frequency is further increased. At the lower frequencies the effect of the distant terminal apparatus is, of course, large. Curves for non-loaded lines are similar except that at the higher frequencies the resistance is lower and the reactance higher.

A feature which has an important effect on the quality of the received telegraph signals is the "vibrating circuit" which was devised originally by Gulstad. This circuit comprises two auxiliary windings on the receiving relay, a condenser and two resistances as illustrated in Fig. 9. A current through the resistance branch of the vibrating circuit moves the relay armature to the opposite contact when the effective operating current, in reversing, approaches zero value. While the armature is passing between contacts, the condenser in the other branch partially discharges through both windings in series, the discharge current accelerating the armature. As soon as the armature touches the other contact, a transient current completing the discharge of the condenser and charging it in the opposite direction holds the armature firmly against this contact until the operating current has had time to become large enough to assume control. The vibrating circuit therefore increases the sensitivity, reduces the time of armature travel, lessens chatter of the armature contacts and makes the operation of the relay more positive. Furthermore, the constants of the vibrating circuit are so proportioned as to minimize distortion of signals, the relay being caused to operate near the steepest part of the received current wave.

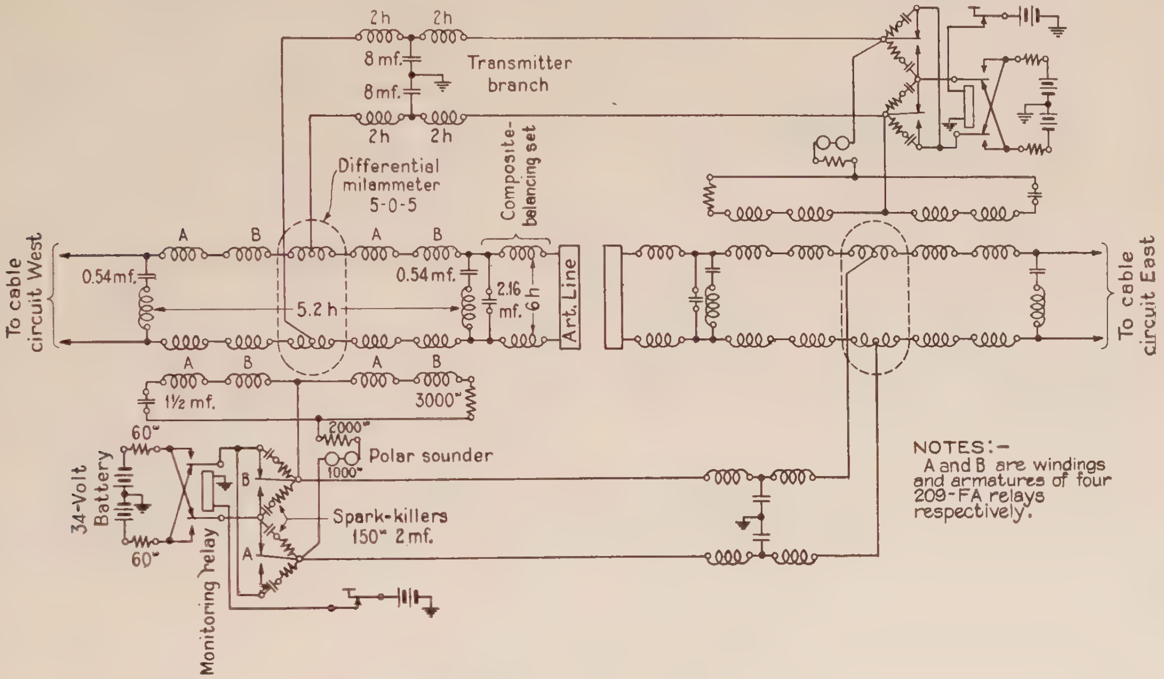


Fig. 10—Through Repeater

The receiving and transmitting relays used in metallic telegraph repeaters are the 209-*F A* and 215-*A* relays, respectively, which are being described in a separate paper. The former is a highly sensitive polarized relay, furnished with vibrating windings, whereas the latter is of the same general construction but less sensitive and has no vibrating windings. The 215-*A* relay is also used in the arrangements provided for facilitating "breaking." In cases where a terminal repeater is operated between a ground-return circuit and a metallic circuit, relays of this type function as receiving relays for the ground return section.

The through-type repeater is a direct-point repeater; the armatures of sensitive polar relays, operated by the line current from one direction, repeat the signal (differentially through the windings of the opposite receiving relays) into the other line in the opposite direction. A simplified diagram of this repeater is shown in Fig. 10. This repeater is a full-duplex repeater but is used on half-duplex circuits without change. As shown, two polarized sounders are provided for reading signals, and a telegraph key controls the operation of local neutral relays, designated monitoring relays, making it possible to send into either line independently, or in both directions at once.

The terminal-type repeater is also a direct-point repeater and is used to repeat signals between a metallic cable section and either a ground-return circuit or a local circuit. Polarized sounders and other monitoring features similar to those in the through-type set are provided. The local circuit arrangements are described in detail in the next section.

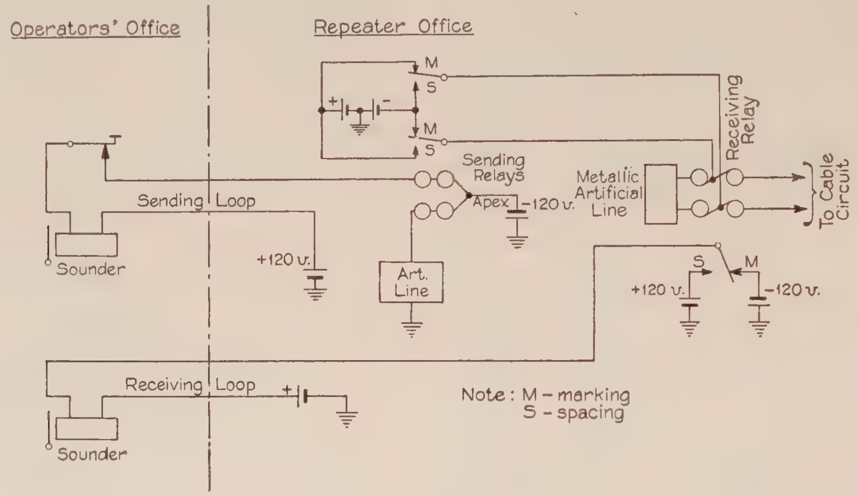


Fig. 11—Terminal Repeater—Full-Duplex Local Circuits

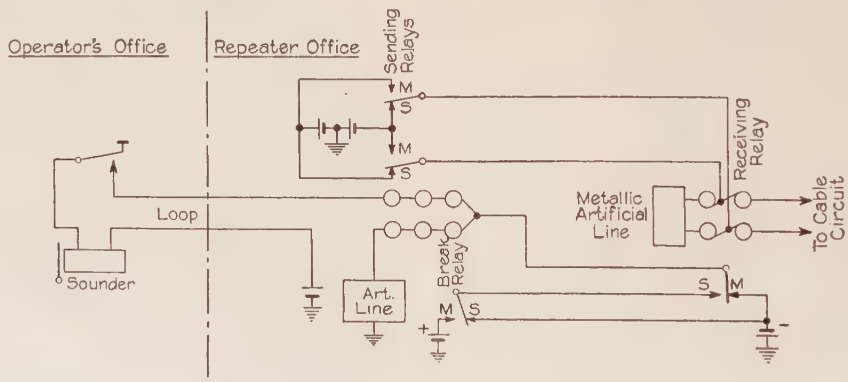


Fig. 12—Terminal Repeater—Half-Duplex Local Circuits

Local Circuits

To avoid supplying battery at outlying points and to facilitate setting up and changing circuits which have a number of stations in the same locality or have branches, a two-wire circuit or "loop" is extended from the repeater office to each operator's station. For the marking or closed condition the current is approximately 60 milliamperes and for spacing it is zero.

For full-duplex service the arrangement is simple, involving the use of a receiving loop and a sending loop as shown in Fig. 11. In the receiving loop the batteries are aiding when the line relay tongue is on marking, and opposing when it is on spacing. Signals may, therefore, be received by the operator by means of an ordinary Morse (neutral) relay or main-line sounder. The sending loop is opened and closed by the operator's key in sending out signals. The sending relays are of the polar type and may be considered to have a biasing circuit which includes the battery connected to the apex point, the lower windings and the artificial line. When the key is closed the effect of the biasing current is overpowered by the loop current, as the latter is twice as great. When the key is opened the biasing current moves the relay armatures from marking to spacing.

For half-duplex service, a single loop is used for both sending and receiving as depicted in Fig. 12.

Signals are sent out in precisely the same manner as in full-duplex and do not affect the metallic line relay on account of the balanced duplex connection. The sending relays, although connected in the loop, are unaffected by received signals as they are differential as regards current from the receiving relay tongue. This is in fact a duplex connection, and it allows the working of the grounded side of the terminal repeater directly into a long circuit having a standard ground-return polar-duplex repeater at the distant station. A suitable artificial line is provided for this purpose.

To facilitate interruption of the sending operator by the receiving operator a "break relay" is also provided, operating simultaneously with the sending relays. To understand its function, assume the key in the loop to be opened; as soon as a marking signal is received from the line, the sending relay armatures will connection. In half-duplex the two local circuits are connected together with the loop in series, and at one repeater, batteries on the receiving relay contacts are reversed and the connections to the loop and biasing windings of the sending and break relays are interchanged.

Local circuit arrangements of the type just described make the metallic repeaters suitable for use in combination with the carrier-current and ground-return polar-duples repeaters used in the plant. This flexibility has been secured by designing the loop circuits to operate with 60 milliamperes current for marking and zero for spacing. Briefly, the flexibility necessary to permit of setting up long circuits with branches is in no wise sacrificed by the use of the several systems.

The essential features of the circuit of the terminal-repeater are shown schematically in Fig. 13.

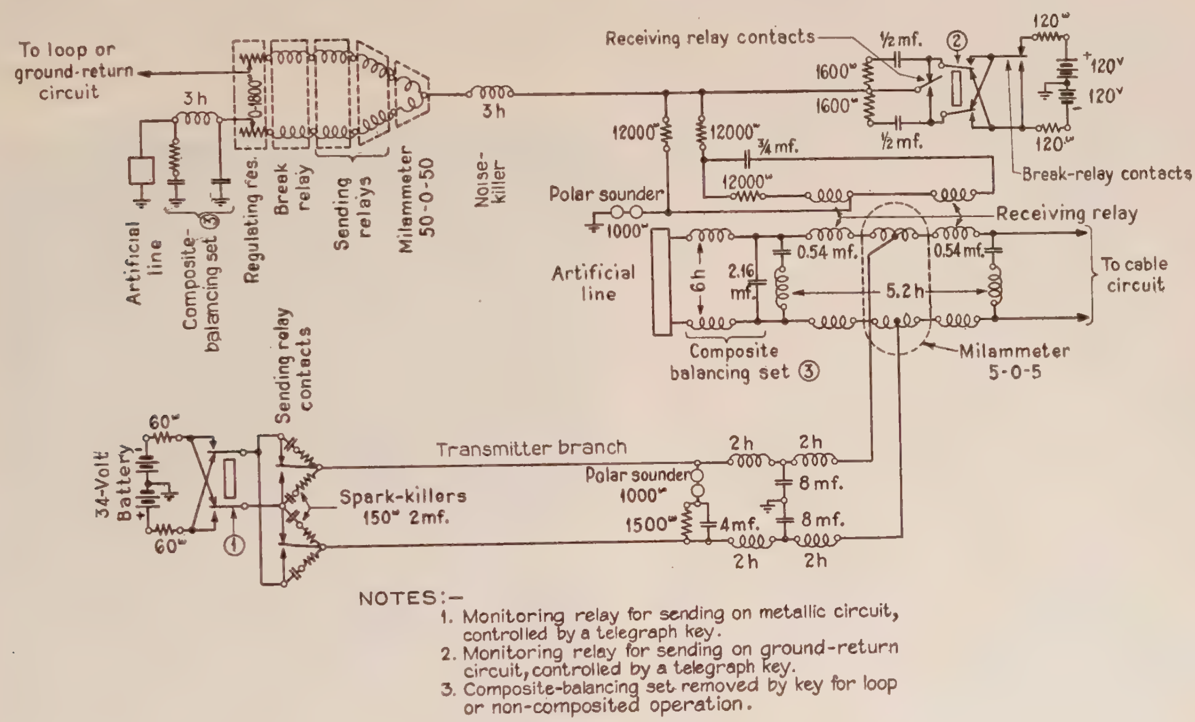


Fig. 13—Terminal Repeater

be moved to spacing due to the current in the biasing windings and the absence of current in the loop. The break relay at the same time connects marking battery to the spacing contact of the receiving relay so that no matter what signal impulses are subsequently received from the line the sending relays will be unaffected. If the break relay were not used, incoming signals would operate the sending relays and be repeated back into the line, reversed. This would result in a slow and uncertain break.

In using two terminal repeaters to connect an operator's office at an intermediate point to a metallic circuit, the loop or loops are connected in tandem between the two repeaters. In full-duplex the sending leg of one repeater is connected to the receiving leg of the other, and vice versa, with a loop in series with each

Superposition on Telephone Circuits by Compositing

In superposing the metallic telegraph on telephone circuits, the well-known "compositing" method is used. This is based on frequency discrimination, the telegraph occupying the range below that of the telephone. For satisfactory results, the telegraph and the telephone arrangements, including signaling, as well as the composite sets, must be designed in conjunction with the line circuits so as to avoid serious interference between telegraph and telephone. Furthermore, the compositing means employed should have but little detrimental effect on the transmission of the three forms of communication operating separately, and must not upset the symmetrical circuit arrangement upon which freedom from external interference depends.

Interference from telegraph and telephone manifests itself in two ways. The first of these is telegraph "thump" which is the name given to a low-pitched noise in the telephone due to a small part of the telegraph current passing through the telephone branch of the composite set and entering the telephone apparatus. The thump, in addition to being audible, may effect the telephone signaling equipment to the extent of causing false rings. In addition to the thump at the transmitting end of the circuit, thump is produced at the receiving end by the vibrating circuit throu h transformer action of the relay windings. In providing protection from thump, both phantom and side circuits have to be considered. The second kind of interference is the flutter effect[4] due to the fact that rapid changes in the telegraph currents momentarily increase the effective resistance of the loading coils, thereby varying the attenuation of the circuit at telephone frequencies.

phone transmission. It supplements the telegraph branch in reducing thump and also serves to limit mutual interference between telephone signaling and telegraph. The repeating coil is also used for deriving the phantom circuit in the usual manner.

The composite set is sufficient to limit receiving-end thump to a harmless amount, but greater protection is necessary against sending-end thump. In order that the additional equipment for this purpose may have the minimum effect on telegraph transmission, it is placed in the transmitter branch where it affects outgoing signals only. It consists of series inductances and bridged capacities to suppress the high-frequency components of the telegraph impulses as in the composite set; the mutual inductance of the coils is made small so that they may be effective in reducing thump in the phantom circuit. In single-commutation repeaters, another coil is necessary in the transmitter branch to prevent excessive phantom circuit thump.

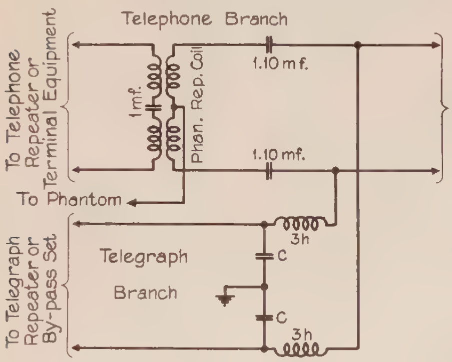


FIG. 14—COMPOSITE SET

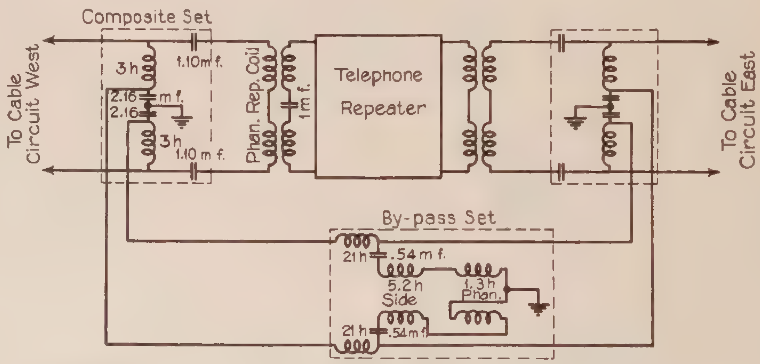


FIG. 15—INTERMEDIATE COMPOSITING ARRANGEMENTS

The telegraph branch of the composite set (see Fig. 14) consists of series inductance and shunt capacity and therefore offers to line currents of telephonic frequencies high impedance and attenuation. It has little effect upon the low frequencies required for satisfactory telegraph transmission, and at the same time sufficiently attenuates the higher frequency components of the telegraph waves to avoid excessive thump. In order that the telegraph branch may be effective in reducing thump voltages in the phantom circuit, the two windings of the retardation coil are made with a negligible mutual inductance, and the bridged capacity consists of two balanced condensers with the midpoint grounded. It has been found necessary to make this retardation coil of very stable inductance by using a comparatively large amount of iron, since a coil with less stable characteristics would cause excessive thump, due to the generation of harmonics.

The telephone branch consists of series condensers and a low-inductance repeating coil or transformer and has high impedance and attenuation for line currents of telegraph frequencies, but has little effect upon tele-

4. See paper by Martin & Fondiller, JOURNAL A. I. E. E., February 1921, page 149.

This coil is connected with its windings parallel-aiding as regards the phantom circuit and therefore is series-opposed or non-inductive for the metallic telegraph operating currents. An examination of the circuits will show that in double-commutation, operation of the telegraph impresses voltage on the phantom circuit only if the two transmitting tongues fail to operate in exact synchronism; in single-commutation, voltage is impressed on the phantom circuit by the normal operation of the transmitter, since the telegraph current' being unbalanced, has a large longitudinal component.

To preserve the duplex balance when using a composited line, a composite balancing set, consisting of a series coil and a bridged condenser, is provided for insertion in the artificial line branch as shown in Figs. 10 and 13.

To protect the receiving relay from interference from the 135-cycle current used for telephone signaling, a resonant shunt is bridged across the telegraph set on the line side of the receiving relay and a balancing shunt is bridged across the set on the artificial-line side. A single coil is made to serve for both of these shunts, one winding being placed in the line side and the other in the artificial-line side.

Twenty-cycle ringing current, which is used for signaling in the local terminal equipment of the telephone circuit, and operation of the telephone receiver switch-hook, give rise to transient currents which tend to harm telegraph transmission. To minimize this effect, a condenser is connected between windings of the repeating coil.

Since metallic telegraph repeaters are spaced about 100 miles (160 km.) apart and telephone repeaters on many circuits about 50 miles (80 km.), means must be provided for passing the telegraph currents around the intermediate telephone repeaters. This is done by inserting an "intermediate" composite set on each side of the telephone repeater and connecting the telegraph branches together through a "by-pass" set. This arrangement is shown in Fig. 15. The intermediate composite set is very similar to the terminal composite set. The by-pass set consists of a retardation coil of high inductance and little mutual inductance between windings, with or without a resonant shunt. The purpose of this by-pass set is to keep the amplification characteristic of the telephone repeater from being affected by currents feeding back through the telegraph branches of the composite sets from the output into the input of the telephone repeater. For four-wire telephone circuits, on which repeaters work with comparatively high amplification, it is necessary to bridge a shunt, resonant at about 135 cycles per second, at one end of the by-pass to prevent excessive feedback at 135 cycles per second and neighboring frequencies. It is grounded in the middle and two coils are provided, connected so that one will be effective for the side circuit and the other for the phantom circuit. For two-wire telephone circuits the resonant shunt is unnecessary.

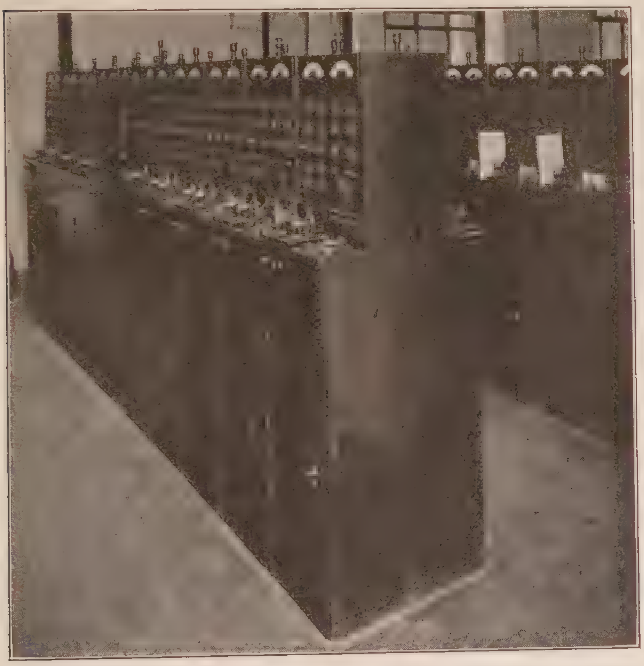


Fig. 16—Installation of Metallic Telegraph Repeaters—Terminal Type

Equipment Arrangements

The terminal-type repeater is assembled as a complete unit at the time of manufacture and therefore the installation work consists only in arranging the repeaters in rows and connecting the line conductors, loops and batteries to the terminal strips. A typical installation is shown in Fig. 16. A terminal and a through repeater are shown in Fig. 17 and Fig. 18, respectively.

A terminal repeater stands 62 in. (1.57 m.) high and occupies a space 14 in. (36 cm.) wide and 12 in. (30 cm.) deep and weighs about 220 lbs. (100 kg). The keyshelf is about 40 in. (1m.) above the floor. On the top of the repeater is mounted the operator's "calling-in" lamp.

The floor-mounted type of through repeater has the same equipment assembly for both the east and west sides and these are practically the same as the portion of the terminal repeater which operates on the cable section. The equipment in the right-hand section of the through panel is for repeating signals from the east line to the west line, and the left vice versa. This repeater weighs about 230 pounds (105 kg.) and occupies the same space as a terminal repeater.

The rack-mounted through repeater was developed after experience with the floor-type had shown how little monitoring attention was required. For that reason the repeater was simplified by the elimination of the line meters and monitoring apparatus. A unit termed a "monitoring unit" is provided for a group of about seven repeaters, and it can be connected into any one repeater by means of cords and plugs. A rack-type repeater consists of three units, the relay and transmitter-branch unit, the balancing-composite unit, and the artificial-line unit. Each of these units consists of a steel panel with necessary apparatus, arranged for mounting on two upright standard I-beams, thus forming a "bay." Generally there are four repeaters, or three repeaters and a monitoring panel per bay. Fig. 19 shows an arrangement of repeaters on racks having a height of about 90 in. (2.3 m.). This type of repeater is upplied for single-commutation operation only, whereas both forms of "floor-mounted" repeaters are supplied for double-commutation operation. Considerable economy in first cost and maintenance is secured by the use of this rack-mounted equipment.

Operation and Maintenance

The metallic telegraph repeaters require comparatively little attention on the part of repeater attendants. Under normal operating conditions one man takes charge of about 24 terminal repeaters or 40 through repeaters. The duties of the repeater attendants consist mostly in maintaining satisfactory impedance balance of the artificial lines against the real lines. This balance is, of course, more exacting for

full-duplex operation than for half-duplex. The capacity balance varies only a slight amount. Variations in resistance balance are caused by temperature changes, the average daily variation being about 6 per cent. The differential milammeter is used as an indicator in determining the resistance and capacity values required to obtain a balance.

The equipment maintenance work required for these repeaters is exceedingly small. For a typical installation of 200 repeaters, the adjustment of relays and general maintenance will necessitate not more than four or five man-hours per day.

The maintenance schedule for adjusting the relays is somewhat variable, depending upon the type of circuit in which they are operating. In general, a 209-*F A* relay in a terminal repeater will give uninterrupted service for two to three months and in a through repeater for four to six months. The 215-*A* relays are adjusted about every three weeks when used as "break" relays and every six months operating as pole-changing relays.

With proper maintenance the transmission of the metallic telegraph system is such as to furnish high-grade half-duplex manual service for distances up to 2000 miles (3200 km.) or more. For the longer distances, the signal propagation time is increased to an amount which makes the time required to "break" appreciable, but not objectionable. For half-duplex printer operation the metallic circuits are satisfactory for speeds up to about 19 dots per second, which corresponds to about 300 characters per minute for the start-stop type of printer.

For full-duplex service, the metallic system affords very good transmission with manual operation for distances up to 1000 miles or more. With careful maintenance of duplex balances, such a circuit is satisfactory for full-duplex printer operation at speeds up to about 16 dots per second, corresponding to about 260 characters per minute for start-stop printers and 385 for multiplex printers.

It is of interest to note that metallic circuits in cable are much more dependable and less subject to interruption than open-wire circuits. Such data as are available indicate that the annual lost time on a long metallic cable circuit is only about one-tenth as great as that on a ground-return polar-duplex circuit of the same length over open wire.

Commercial Use

At the present time there are in operation in the Bell System about 55,000 miles (89,000 km.) of metallic telegraph circuits of this type of which 30,000 miles (48,000 km.) are worked on a composited basis. Approximately 20 per cent of the total mileage is operated full-duplex. There are now installed in the plant about 430 through repeaters and 1050 terminal repeaters.

Discussion at Annual Convention

A NEW TYPE OF SINGLE-PHASE MOTOR[1]

(Bergman)

Chicago, Ill., June 27, 1924

V. Karapetoff: An impression may be gathered from the paper that the power factor of the motor is improved because the squirrel-cage winding is highly inductive. It seems to me that the squirrel-cage winding necessarily has to be highly inductive so as not to interfere with the series characteristics of the motor at the start. If it were not for an additional mechanical complication (Fig. 2), it would be better to make this winding less inductive at and near synchronism. A transformer diagram at constant current will readily show that the common flux is lagging behind the primary current at a non-inductive load more than at an inductive load. Therefore, the less inductive the squirrel-cage winding, the more the flux ϕ_f is lagged behind I (Fig. 4). But the flux in T must be in time quadrature with ϕ_f in order that the total e.m.f. between the brushes be equal to zero. Therefore, lagging ϕ_f also causes ϕ_t and E_t to lag more behind I; in other words, it causes the vector of the current to come nearer that of the total voltage E. Thus, the power factor is improved even though the squirrel-cage winding has a high inductance, and the power factor would be improved more, if it were advisable to reduce the inductance of this winding in normal operation.

E. Bretch: About twenty to twenty-five years ago when the single-phase motor business was developing, considerable trouble was experienced with off-frequency circuits. In those days the single-phase generators were comparatively small and were designed for lighting service. When motors were connected to them, difficulty was experienced in keeping up the voltage and the generator was often speeded up to build up the voltage.

Single-phase motors with a centrifugally operated device to change from repulsion to induction were in difficulty on these off-frequency circuits, as they would short circuit the rotor at a fixed speed which on high frequency would be too low for the motor to come up to speed, causing severe fluctuations on the line as well as annoyance to the motor user. In considering the problem of constructing a motor that would be responsive to slip rather than speed in making the change from repulsion to induction, the writer conceived the idea of using a rotor with both the repulsion winding and the short-circuited winding permanently in circuit, the short-circuited or squirrel-cage being "loosely coupled" so as to be inactive until near synchronous speed.

During 1904 and 1905 several experimental motors were built and tested, and a patent (No. 848719) was issued to the writer April 21, 1907. This patent covered broadly the idea of a commutated winding at the surface of the rotor, a squirrel-cage or short-circuited winding beneath the commutated winding and a by-pass or leakage path whereby the magnetic flux would pass between the squirrel-cage and commutated windings at stand still, or low speeds, when the alternations of the flux were high; but at, or near synchronous speed the flux of slip frequency would penetrate the squirrel-cage and give the motor the constant speed characteristic. The squirrel-cage from its inductive relation to the commutated winding also eliminated the sparking at the commutator.

During the next few years several hundred of these motors were placed in service, and were successful electrically and

1. A. E. E. E. Journal, Vol. XLIII, July, p. 599.

mechanically. However, due to the prejudice, at that time, against single-phase motors with brushes in service continuously and to the fact that some people insisted "wrongly" upon making the no-load losses a criterion for judging the efficiency of the motor, this line of motors was later equipped with a short-circuiting device and the squirrel-cage omitted. A description of these motors with the double-wound rotor was published in the *Electrical World*, July 1907.

Various combinations and proportions are possible between the three elements of the combination, the commutated winding, the squirrel-cage winding and the magnetic by-pass. In the motors as originally constructed, the control of the flux in the by-pass was accomplished by proportioning the cross section of the iron in the magnetic bridge between the two windings, and depending on the saturation of the iron.

Various other methods have been proposed, such as short-circuited loops encircling, or partially encircling the by-pass, making the by-pass of solid magnetic material and utilizing the choking effect of the eddy currents in the solid material, making the squirrel-cage conductors themselves of magnetic material, air gaps in the by-pass, as well as the one outlined by Mr. Bergman. The methods of using solid magnetic bars as a by-pass, and of leaving a thin bridge of iron in the rotor punchings between the two windings, have been in use for many years.

As to commutation, Mr. Bergman's statements are well founded. Only a few weeks ago, one of these motors with the double-wound rotor that had seen service for fifteen years, was returned for repairs. The rotor was perfect, and the commutator not as much worn as would be expected on a direct-current motor of similiar age.

As pointed out in the specifications of the above mentioned patent, the fact was then noted that the power factor was higher than that of the straight induction, but the reason for it was not understood. The problem had been to produce a sparkless motor that would change from repulsion to induction in response to slip rather than speed, with no particular thought of increasing the power factor.

I have a test sheet, dated Jan. 17, 1907 of a ¼ H. P. motor of this type, showing practically the same characteristics as Mr. Bergman's tests:

V. A. Fynn: A thing which strikes one in reading Mr. Bergman's paper is his disregard of that which has been accomplished by others. Others have worked on the very type of motor which Mr. Bergman now claims as new, have built such machines and have long ago published their results.

The motor of Mr. Bergman's Fig. 2 has a squirrel-cage and a commuted winding on the rotor but both of these windings are in the same rotor slots. Series conduction and induction motors so built were proposed many years ago by Lundell, they have no magnetic shunt or bridge between the two rotor windings and differ widely from the machine shown in Mr. Bergman's Fig. 3. The laminations shown at one end of the squirrel-cage are not the equivalent of magnetic shunts.

The motor of this Fig. 3 was patented in this country on September 2, 1907. See U. S. P. 848,719. The patentee, Mr. Edward Bretch, of St. Louis, has built and sold thousands of these machines and the fact that his patent is about to expire does not rob him of his priority. The motor shown by Mr. Bergman in his Fig. 3 does not differ from the Bretch motor in principle. There is nothing new about this machine. It differs from that of Lundell in that it provides a magnetic bridge between the two rotor windings.

In discussing the theory of the so-called repulsion motor, Mr. Bergman omits all consideration of the all important self-compensating feature of such machines. It is useless to go into this matter here since this point is fully explained, for instance, in my "Classification of Alternating Current Motors," PROCEEDINGS A. I. E. E., May 1915, page 972. Nor does Mr. Bergman's theory take into account the fact that in the motor of his Fig. 1 the rotor ampere-turns are in excess of the co-phasal stator ampere-turns.

The power factor of the Bretch motor is high at some loads because below synchronism both the squirrel-cage and the commuted windings contribute to the motor field, a condition which results in a retardation of the phase of the resultant motor field as against that of the motor field which the squirrel-cage alone would produce. Just how such a retardation affects the power factor of a single-phase motor was shown by me, for instance, in "A New Single-Phase Commutator Motor," see *Proceedings* I. E. E., March 8, 1906.

It would be interesting to know just how the "field winding" of a motor, see page 3, column 2, line 13 from last of Mr. Bergman's paper, can contribute "about one half of the output." Field windings do not transfer energy. The fact is that the field winding of which Mr. Bergamn speaks, and which is shown in his Fig. 4 at F, does not exist. His motor is excited from the rotor and not from the stator as he supposes.

I cannot see how the flux "which acts as self-induction" spoken of on page 4, column 2, line 16 from last, which must be a leakage flux merely linking with the two rotor windings, can possibly produce a torque available on the shaft of the motor.

As to the short circuit M in the path of any flux threading the magnetic bridge between the commuted and the squirrel-cage windings, this is by no means novel. I have patented such a shield on June 6, 1911, see U. S. P. 994,381 and similar means on November 28, 1911, see U. S. P. 1,010,135.

I may further point out that I have done considerable developing work in connection with single-phase motors having a commuted and a squirrel-cage winding on the rotor with a magnetic bridge therebetween, producing different forms of series induction motors (Mr. Bergman would call them "repulsion motors") with an added "sunk" squirrel-cage and have fully discussed the theory of these machines. I refer to my several and old patents on this subject and to my paper "Single-Phase Squirrel-Cage Motor" which describes a machine showing considerable advance over the Bretch motor. Among other features my motor shows leading power factor at no load and practically unity power factor at most loads. When operated without auxiliary or external phase-compensating means it exhibits a power factor very near unity over a considerable range of loads as evidenced by Figs. 15, 16, 22, 25 of the paper last named, see PROCEEDINGS A. I. E. E., October, 1915.

Recently in discussing my paper entitled "A New Self-Excited Synchronous Induction Motor," Mr. Bergman found fault with the presence of a commutator and notwithstanding the fact that the machine in question is compensated at all loads and that its commutator carries nothing but exciting current and unidirectional exciting current at that. Now Mr. Bergman advocates a motor which although it has a commutator is not compensated at light loads, is not fully compensated at any load and is of such design that the commutator carries load current of full line frequency. If the criticism he directed against my machine is justified, is it not obvious that the same objection applies to a prohibitive extent to the motor he now describes.

P. M. Lincoln: The motor characteristics given in the paper, both the calculated and the observed, are very satisfactory. They show a very good shape of speed-torque curve, and I would like to ask about the commutation. Are they satisfactory in commutation, both at start and under running conditions, and how is that commutation obtained?

They are so satisfactory in comparison with the standard squirrel-cage polyphase induction motors, that undoubtedly if they can be made at a cost comparative to the cost of the standard squirrel-cage motor, they would receive a large application in commercial practice.

I would like to ask how about that cost. How much above the standard squirrel-cage motor will it be?

Also, how large a motor can be made in this manner?

G. H. Garcelon: Mr. Bergman's description of his conception of this motor is very interesting to me, as it varies somewhat from my own experience a few years ago in carrying out the commercial development of a line of motors similar in principle and operating characteristics.

Designers have long realized the more or less uncertain operation and expensive construction of mechanically operated devices used to combine the desirable characteristics of two or more types of motor, and have striven for a purely electrical means of securing such combination.

For starting and accelerating, the series and repulsion windings were most suitable, with the repulsion type lending itself more readily to commerical use, because of the following characteristics:—

1. Armature voltage is independent of line voltage, permitting reconnection of stator for different voltages without affecting the rotor winding.
2. Armature voltage may be selected for best mechanical and electrical design.
3. Simplicity of brush rigging.

For running, the squirrel-cage induction winding was most desirable because of its close speed regulation and mechanical simplicity.

Considering also the well known generating characteristics of the induction motor above synchronous speed, these two types of winding seemed to be ideal for combination except for the fact that their starting characteristics were normally antagonistic; as the squirrel cage would draw large currents at standstill and set up a field in opposition to the normal repulsion-motor field, greatly reducing, if not entirely annulling, the desirable starting characteristics of the repulsion winding.

The problem then seemed to be that of minimizing the effect of the squirrel cage at starting, and using it as much as possible after the rotor attained speed.

It was appreciated that the high-frequency rotor flux at starting could be damped to a great extent by using a high-reactance squirrel cage, and that the circular rotating field produced by the repulsion winding at synchronous speed would induce a low frequency in the squirrel cage which would minimize its reactance and cause it to develop appreciable running torque.

Experiments with various means of accomplishing these results proved the correctness of the theory, although several presented structural difficulties.

In order to secure power factor compensation to the marked degree shown in the paper, abnormally large magnetic parts are required so that saturation may be avoided.

By alterations in rotor design this type of motor lends itself to a variety of speed-torque characteristics and still maintains the other general characteristics mentioned by Mr. Bergman.

A line of motors of this general type, having a somewhat drooping speed-torque curve, has been on the market for three or four years and has been giving excellent service on such applications as pumps and compressors as well as in general service.

H. C. Specht (by letter): The motor with such a performance as described will necessarily be somewhat larger in dimensions than the ordinary repulsion-starting induction-running type. It also seems to me that the mechanical construction of the rotor laminations is such that very expensive equipment will be required and the punching cost will be high.

During the development of a similar motor various rotors were used, and it was found that those having a high reactance and low resistance in the squirrel cage showed a break in the speed curve at lower torques than those with relatively higher resistance and lower reactance. It was also found that the high-reactance rotors showed higher current and lower power factor at light loads than did the rotors of relatively higher resistance. However, the low-resistance rotors showed better speed regulation with better efficiency and power factor under overload conditions. This only goes to show the variations of some characteristics at the expense of others, and indicates the possibility of considerable choice in performance.

The improvement in power factor due to the use of the squirrel-cage winding with low resistance and high reactance becomes effective only after the load has caused the speed to drop below synchronism, whereas above synchronism the reverse effect is true. Therefore, it is not desirable to keep the speed of the motor above synchronism over a very large portion of the operating range. There is really very little object in comparing the power factor with that of a straight repulsion motor as this type is not suitable for general application. If we compare the power factor of this motor with an induction motor having a short-circuited armature winding, the increase in favor of this type of motor is very marked due primarily to the lack of cross-field magnetizing current being reflected in the primary.

Mr. Bergman points out that the thin metal strip in the slit between the two windings improves the commutation under running conditions, and this is no doubt true, but, inasmuch as it is a very easy matter to secure excellent commutation near synchronous speed and the metal strip decreases the starting torque to some extent, as well as slightly increases the losses, it would seem to be an undesirable addition.

William Cramp (Communicated after adjournment): With reference to the article by Mr. S. R. Bergman in the Journal of the A. I. E. E., July, 1924, it may interest your readers to refer to the *Journal* of the London I. E. E., Vol. 57, page 287, wherein I think they will find the prototype of Mr. Bergman's new machine.

Several motors working on this principle were designed and sold about 1904, but by his ingenious addition of metal plates in the slot openings to improve commutation, Mr. Bergman has undoubtedly improved the machine, especially when it is required for large horse power. The original motors gave no trouble at all as far as commutation was concerned, but they were built chiefly for driving fans, where the starting conditions are easy and the power comparatively small. I should like to add that my experience with these motors showed that the fall in speed from nothing to full load was a good deal more than that of the ordinary induction motor. It is difficult to tell from Fig. 8 of the Journal what the regulation on Mr. Bergman's machine is like, and it would be interesting if he could give further information on this point.

S. R. Bergman: In regard to Professor Karapetoff's statement, I pointed out in my paper that the reason for the good power factor in this motor was the action of the squirrel cage which is rather curious due to the fact that this squirrel cage possesses a high reactance. Professor Karapetoff is correct in his statement that the motor characteristics would be even better during running conditions if the squirrel cage possessed less reactance, a fact which I believe is illustrated in my paper by the description of the first motor having an adjustable reactance of the squirrel cage, this reactance being great in starting and low in running. Thus, I believe that Professor Karapetoff's conclusions are in full accord with the theory given in my paper.

Mr. Bretch has contributed a very interesting discussion showing that he, at a very early period, had some quite interesting ideas. Of course in the light of our present knowledge it may be readily understood why the motor built in accordance with the Bretch patent was abandoned.

The motor which is described in my paper is mechanically and electrically something quite different from the Bretch motor. It is, in my judgment, not possible to satisfactorily control the flux in the by-pass by proportioning the cross section of the iron between the two windings so as to depend upon the saturation of the iron for results.

Mr. Fynn discusses the novelty of this motor at some length, referring particularly to the Bretch patent. He forgets however, the very important fact that the Bretch motor has been dis-

continued in production. The motor proposed by Lundell I am not familiar with, but it seems from Mr. Fynn's description to be substantially different in principle.

Mr. Fynn seems to severely criticise the theory given in my paper. I wish to suggest that Mr. Fynn read the paper giving the details of the theory, which was presented at this Convention by Mr. West, entitled: "The Theory of the Squirrel Cage Repulsion Motor." Mr. West's theory is based on the general equations for the alternating current motor, single or polyphase, as first published by Steinmetz. Mr West's theory is carried out in complex quantities and agrees with the few graphical illustrations I have given in my paper. Results of careful tests at all speeds for both rotations, check our theory surprisingly closely. It seems therefore, plausible that such a theory is correct and it has well served our purpose of predetermining a complete line of motors of this type, which has recently been put on the market by the General Electric Company.

Mr. Fynn further states that the two windings into which we have resolved the field winding, do not exist and furthermore that field windings do not transfer energy. I wish to point out that we have built motors with two field windings and by inserting wattmeters in these windings it is an easy matter to check our theory.

Mr. Fynn also states that he cannot see how the flux, which acts as self induction, can possibly produce torque. The flux which penetrates the space between the two windings of the armature may be considered leakage flux with respect to the squirrel cage winding and mutual flux with respect to the repulsion motor winding. This is in accordance with the general accepted views on leakage and mutual flux. Hence, the flux which acts as self induction with respect to one winding, acts as torque producing with respect to the other winding.

Mr. Fynn also seemed to criticise the name of "Repulsion Motor" which I have given to the commutated winding. The brushes on this winding are short circuited and therefore, conform to that type of machine which was first brought out by Professor Thomson and called by him "Repulsion Motor." Professor Thomson's contribution in inventing the repulsion motor is one of the most notable contributions to the electrical art and in recognition of this contribution I think we should maintain the name "Repulsion Motor."

Finally, Mr. Fynn has again brought up for discussion, his paper called "A New Self Excited Synchronous Induction Motor." This paper, which was presented at the Spring Convention in Birmingham, Ala., describes a polyphase induction motor possessing a commutator as well as slip rings having two armature windings in addition to two field windings. I merely have pointed out that in the case of polyphase motors which do not need to depend upon a commutator for operation, it certainly is a complication to add a commutator as well as slip rings, as well as four separate windings. A polyphase motor starts very satisfactorily with a squirrel cage and all these complications have been added to a polyphase motor in order to improve the power factor. As is well known, a single phase motor is not self starting, hence there is a good reason in order to start such a motor, to add a compensator. I wish to emphasize that in my motor the armature possesses only a single wire winding and the field also only a single winding. Furthermore, my motor does not possess any slip rings. It is therefore, obvious that this new single phase motor is much simpler than Fynn's polyphase motor.

Turning now to Mr. Lincoln's inquiry as to the commutation in this motor, the theory of commutation is given at some length in my paper. The commutation in this motor is perfect during running conditions and as stated, is as good as that of a direct current motor with commutating poles. The reason for the good commutation is the fact that the motor runs near synchronism and the leakage flux is damped out by the squirrel cage and the metal wedges. The effect of the squirrel cage and these metal wedges is therefore, similar to the action of commutating poles in a direct current machine, since both of these devices take care of the self induction of the coils undergoing commutation.

As to Mr. Lincoln's inquiry about the cost of this type of motor, I may state that the material is efficiently utilized and that due to the simple mechanical arrangement of the windings, the process of manufacture is attractive.

As to how large a motor we can build in this manner is a question which is rather difficult to answer. There is nothing in the theory of this motor which would indicate that size would be a limiting feature, which I believe will answer Mr. Lincoln's question.

Mr Garcelon states that a few years ago he brought out a line of motors similar in principle and operating characteristics to this new motor. I believe Mr. Garcelon is referring to a motor built on the principle of using a squirrel cage in the same slots as the repulsion motor, this squirrel cage consisting of high resistance magnetic bars. This motor will give quite different operating characteristics from the motor I described. I go so far as to state that, in my opinion, the underlying principle is dissimilar in these two motors and the operating characteristics certainly justifies this statement.

There is one statement made by Mr. Specht which I wish to briefly touch upon. Mr. Specht states that the metal strips decrease the starting torque and the core loss and furthermore, as it is an easy matter to secure perfect commutation near synchronism it would seem undesirable to add these wedges. Of course before standardizing such wedges we built numerous motors of identically the same design with and without such wedges. The efficiency and the starting torque showed no difference, but the commutation was markedly different inasmuch as the omission of these wedges made the commutation unsatisfactory. I agree with Mr. Specht that these wedges introduce small additional losses but as they improve the commutation, the commutation losses are eliminated and thereby counter-balance the losses in the wedges. Therefore, this is the explanation why the efficiency is not affected by these wedges.

SENSITIVE RADIO-FREQUENCY RELAY[1] (Lewis)

Chicago, Ill., June 25, 1924

J. Slepian: The device described by Mr. Lewis has several distinct elementary parts performing rather distinct functions; there are the filament and grid, giving the usual detector action, there is a thermally responsive element and there is a contact which opens and closes.

A pertinent question seems to me to be whether anything is gained beyond compactness in this rather ingenious combination of all these elements, and whether it is necessary to sacrifice the best performance of some of the individual elements for the sake of getting this compactness.

Now it does seem as if the detector action of the tube has to be modified. A standard plate surrounding the filament in the usual way cannot be used because that would give too large a volume for the thermally responsive part. Instead a very small plate must be used and thus a detector element of higher impedance than the standard tube results. There appears then to be some disadvantage here. On the other hand if one tries to separate the two functions, and use standard thermionic tube to deliver electrical power into a thermally responsive element, great difficulty will be encountered in constructing a thermally responsive element with sufficiently high resistance to work with an ordinary tube.

By having the michrome ribbon heated directly by electron bombardment, a thermal element results which has a high impedance. There is therefore considerable advantage in the combination.

I would like to call attention to some points with respect to the operation of contacts in high vacuum. At first sight it

1. Journal A. I. E. E., Vol. XLIII, November, p. 1031.

would seem that a very great advantage is to be obtained by working contacts in a vacuum. In a high vacuum an arc is impossible, and since the principal trouble with contacts which handle any considerable power is the destructive arcing by putting the contacts into a vacuum one would expect to eliminate the arc and to be able to handle tremendous power for an indefinite time.

This argument seemed so plausible to me that a number of years ago I actually carried on a considerable number of tests on contacts opened and closed in vacuum. These contacts were opened and closed by magnetic means, not by the method shown here. The results I obtained were very disappointing. After working on it quite a bit I arrived at the following understanding as to why better results were not to be expected.

As a contact is opened, the area of contact reduces very rapidly from a finite area down to a very small value. Just at the last moment of break, the resistance of the contact goes up enormously, and the voltage of the circuit begins to concentrate on it, so that whatever the voltage of the circuit is it will all act on this last contact.

It is not very difficult to calculate the temperature rise at a point of contact between two materials when a voltage is applied to it. As I remember the figures, the formula comes out

$\frac{E^2}{33\,K\,\rho}$, where E is the voltage, K the heat conductivity and ρ

the electrical resistivity. Taking the heat conductivity of the metal as unity, and 10^{-6} as the resistivity, for 1 volt, we get 3000 degrees. That is, the last point of contact, for one volt in a circuit, will be necessarily raised to 3000 degrees. Hence, there must be melting of the very last point of contact, and for the heavier currents that I dealt with in my own experiments I found that the contact soon roughed and became useless after a few operations, since it was impracticable to apply heavy mechanical pressure in the vacuum. Furthermore, the volatilization of metal spoiled the vacuum and permitted arcs to flow.

HIGH-VOLTAGE IMPREGNATED PAPER CABLES[1]

(Del Mar and Hanson)

Chicago, Ill., June 27, 1924

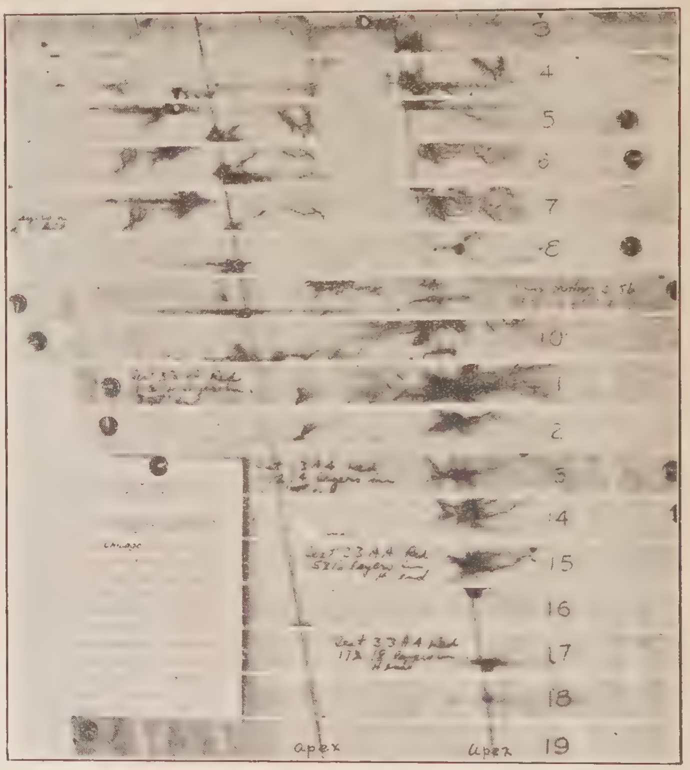
D. W. Roper: A point which should be more prominently set forth is that as the operating voltage of a cable increases, the quality must improve. What is needed at the present time is some method of measuring the quality of the insulation and determining the maximum operating voltage for which a given quality of cable is suited, and to which it should be limited. There are also needed some other tests to be applied to cable at the factory in order to determine whether it will be satisfactory for the service for which it is intended. Apparently some further research as well as co-operation between the manufacturing and operating companies is needed in order to develop the proper tests for this purpose.

W. F. Davidson: The authors refer to the difficulties experienced a few years ago on the use of very stiff impregnating compounds and the resultant formation of voids when the cable was bent. They imply that this difficulty has been entirely avoided by the use of lighter compounds but I am of the opinion that their statement is a little too optimistic. Some day we may reach the point where voids are not developed by bending.

The authors call attention to the fact that many of the phenomena associated with air films in cables cannot be fully explained on the simple hypothesis that ionization results from a stress in the air film K times that in the solid portions of the dielectric. This is a natural consequence of the fact that the air films are not infinite in extent but really are of comparatively small area so that creepage phenomena play an important part. A number of very interesting possibilities are suggested by the considerations of stress distributions with alternating fields and with continuous fields. Some theoretical work has already been started and experimental work has been mapped out. Until more is known of the values of the numerous physical constants it will be impossible to complete studies along this line.

A rough shop method for determining solidifying point of compound is described. Rather more consistent results can be obtained by taking the temperature-viscosity curve by means of a MacMichael viscosimeter. This instrument gives results of very satisfactory precision with a minimum of observational error. Probably in point of time it is rather faster than the method described in the paper. Studies of a considerable number of cable samples have indicated the possibility of getting the temperature-viscosity curve over a wide range from three or four points after the general characteristic has been determined.

R. A. Paine, Jr.: The authors inferred in their paper that



if an air film can be maintained at low pressure, they are thus able to get a flat power-factor characteristic. I would be glad if the authors would be able to give us some data or results of any experiments that they have been able to make along that line, as it would seem that it would be almost impossible to maintain this air film at low pressure.

The authors speak of the ratio of oil to paper as a means of determining saturation. I am glad to note they say they are going to do some further research work along that line in order to get a better method of determining the degree of saturation. It seems to me that they are missing one point, and that is what we really want to know is if the complete volume inside of the cable is filled. What we really ought to have, I believe, is the total volume, and then take into account the total amount of paper and the total amount of oil in it rather than work on a ratio basis.

There are at least three of the American cable manufacturers now who can make cables with almost no wrinkles, practically

1 Journal A. I. E. E., Vol. XLIII, October, p.950

none, and I think within the next year we ought to be reasonably sure of getting cables that will have no trouble standing up in operation over a period of years.

H. Halperin: I wish to emphasize the remark of Mr. Del Mar, that there is a very urgent need for securing uniformly good cable insulation. In a 10-mile line of three-conductor cable with 350,000 cir. mil. sector conductors, there are about 29,000 sq. ft. of copper surface from which a failure might occur; and defects in a comparatively very small per cent of the total insulation can easily result in poor operation. In dissecting test and service failures of 13-kv. and 35-kv. cable in Chicago, the insulation immediately adjacent to the failure has frequently been found radically different in construction and impregnation from the remaining portion of the same length.

In connection with the carbonized tree patterns that were found by Mr. Del Mar, we have found that these also appeared in the endurance tests at 127-kv., three-phase on the three-conductor, 35-kv. cable. In the illustration shown herewith, these designs were taken from the conductor insulation in a joint 2 in. outside of the belt. Usually the carbonized patterns in the cable were most pronounced at or near the apex of the sector, that is, the portion pointing toward the center of the cable. The most pronounced formation of these tree patterns was found in cables which withstood the test for the longest time.

The authors state that the compound "X" has been found in the outer conductor insulation and inner belt insulation. Frequently in three-conductor, 35-kv. cable we have found it throughout the conductor insulation and in some cases the formation was most marked adjacent to the copper.

In the latter part of the paper a curve of power factor against temperature for a cable with 15 per cent rosin in its compound shows the power factor at 80 deg. cent. to be over 9 per cent; and the discussion is to the effect that the presence of rosin materially affected the critical temperature in cumulative heating. This effect is negligible with the many European cables being made and which have been made, with higher percentages of rosin than 15 per cent and power factors about half or less than those shown in the curve *B* for temperatures of 60 and 80 deg. cent.

E. R. Thomas: I would like to contribute a little discussion to the paper by Messrs. Del Mar and Hanson. We have made some tests in New York of high-potential stresses on impregnating compounds. I will give somewhat of a resumé of our tests. We used some special glass test tubes, the outer diameter of one being a few mils less than the inner diameter of the other. In the larger test tube was put a small quantity of mineral oil, heated very slightly, enough to form a liquid state, dropped the other tube inside and in that way obtained a very thin film of impregnating compound. This was subjected to a high-voltage gradient by putting a mercury electrode in the inner tube, immersing the outer tube in salt water and then applying a high potential between electrodes.

The visual phenomenon which occured when putting this under stress was a very light corona discharge in the tube. There was no occluded air in this very thin film which would be quite readily discernable by holding it to the light. After this had been on test for some two hours, some changes went on. We had sealed the tube at the top with a small rubber balloon which became inflated and thus gave evidence that some gas was given off. The noted change occurring in the oil was that it goes over to a state of solidification and from its resemblance we had termed it Swiss cheese. It changes from the oil, which is amber, to a rather yellow waxy substance with numerous void spaces in it giving a Swiss-cheese appearance.

Several batches of this were run until we had a sufficient quantity to make a breakdown test. This was melted into an oil cup, and, by the way, goes back to a waxy substance after being melted. The breakdown test showed that there was no practical difference in breakdown strength from the original compound. We also have found that by modifying a mineral oil compound with some other things this changeover in substance can be somewhat lessened and I believe that there is a considerable field of research open in this line.

H. F. Randolph: The results obtained by Messrs. Del Mar and Hanson on overstressed cables are particularly interesting, since we have noticed a great many of these points in our investigation in the after-performance of underground cables in the past year.

It appears that dielectric loss in high-voltage paper cables has been reduced to a minimum and is no longer a controlling factor. It would be interesting to know if any other qualities were sacrificed in order to accomplish this.

The authors state that although very high voltages are obtained on samples of three-conductor cables, it is practically impossible to break them down in laboratory tests, but still failures occur in actual operation of these same types of cables, although operating conditions previous to, and at the time of, failure are apparently normal. We have examined samples of cable adjacent to some of these failures and have noticed a similar condition to that mentioned by Mr. Del Mar, the perforation of the layers of paper, but we have not noticed any tree designs. It would be interesting to know the approximate voltage that would be apt to cause this condition.

I would also like to ask the question as to whether a percentage of rosin-oil compound mixed with a mineral-oil compound would have any decided effect on the life of the cable.

A. H. Kehoe: I think the real value of the so-called power-factor test is not brought out in the Del Mar-Hanson paper. The test consists in the change in power factor on test samples of cables with an increase in voltage of the proper amount. It may be true, as stated in the paper, that the curve of power factor increases, diminishes, or stays constant, with a certain line of material, but after a certain kind of cable is brought through a factory and this characteristic determined, there is but one thing that changes the quality in the cable and this resolves itself into "air" in the cable. With an increase of air in a cable the power-factor curve will be increased over the normal characteristic as soon as the ionization point of the air is arrived at on increasing the voltage for the power factor test.

In the same paper there is described results of tests at two and one-half times normal working stress. It should be realized that the power-factor test intended to indicate the presence of air by change in power factor is not a matter of normal working stress on the cable. It is a matter rather of stressing the cable insulation up to certain definite values where air (if it be in the insulating structure) will be ionized. This becomes a matter of physical dimensions and properties of the insulation and has no definite relation to normal working stress.

In reference to the theory of ionization the following statement is found on the third page of the paper by Messrs. Del Mar and Hanson: "It is our opinion that this theory is not complete and requires a new interpretation; and we believe that the surface leakage phenomena described, suggest the necessary modification." The surface leakage phenomena mentioned in the above statement refer to the characteristic fern-leaf discharge path between paper wrappings, frequently, if not always, found after subjection to high-potential test, that is, a stress considerably higher than normal.

The configuration of this type of discharge is typical of all high-frequency discharges, such as lightning, static discharge over insulators, etc. It is the result of a destructive groping or reaching about for the weakest path, which in this case happens to be along the paper surfaces. The high impedance at these very high frequencies is the cause of these discharges not being directional. They do not necessarily follow air or gas pockets but actually form their own pockets by generation of gas as they travel along.

Apparently, Messrs. Del Mar and Hanson have confused the above phenomena with the slow, steady glow discharge which occurs in gas pockets at lower voltage stressing and constitutes the true ionization with which cable engineers are concerned. The effects of this are much more gradual and the range of travel much more limited. The result is a slow chemical change or disintegration, not necessarily accompanied by charring. It is more to be feared than the first-mentioned phenomena, for it might occur at normal operating voltage, while the first, as far as my observation has gone, always requires considerable over stressing.

This second type of discharge did not escape their observation for they give a very accurate description of its effects. Their explanation, suggesting the formation of fatty acids, seems very reasonable and probable. There is not a sufficient quantity of nitrogen present to form nitro products.

The various methods of factory test and control they describe are now being followed by most, if not all, of the cable manufacturers. Most of these have proved reliable guides to a better quality cable. A few have not. In particular, no reliable test has yet been developed to determine the degree of impregnation. The method of extraction with carbon tetra-chloride or other solvents has not proved satisfactory. So far, the old method of visual examination and expert judgement has not been displaced.

I was very much interested in their characteristic "breakdown versus time" curve, given in Fig. 15, and fully agree with their statement that such curves are of no value in determining ultimate life at normal voltage by extrapolation, due to the fact that other factors of a deteriorating nature enter into action as time goes on.

C. F. Hanson: I should like to make a reply to Mr. Halperin's statement regarding the last part of the paper, referring to Curves A and B. We do not say it is not possible to secure lower power factors using rosin than are given by Curve A, nor do we say that we always need to get as high a power factor as given by Curve B. These curves were given simply to show the relative values when we do and do not use rosin. They are the results of three cables, all treated identically, the same oil being used, only that in one case 15 per cent of rosin was added; while in the other cases, no rosin was added.

The data were obtained some years ago when oil refineries had not developed in refining petrolatum the technique applied today. With present-day oil, lower power factors may be obtained than those shown in Curves A and B.

Wm. A. Del Mar: Mr. Roper is right in pointing out that as the operating voltage of a cable increases, the quality must improve. The term "quality," however, is a somewhat indefinite one and should not be interpreted as applying to all of the characteristics of the cable. Some discrimination is required to determine which characteristics should be improved as the voltage increases. For instance, the quality of the paper as set forth in ordinary specifications should be decreased rather than increased for higher voltages. By this I mean that more or less wood pulp should be allowed. Similarly, flexibility requirements should be reduced rather than increased in the case of high-voltage cables so as to permit the use of materials of greater dielectric strength at the expense of the mechanical qualities.

It is also quite possible that the dielectric loss should not be too low in cables for very high voltages in order to give an opportunity for the dissipation of local transients in the insulation. The main quality which requires to be improved as the voltage is raised is the saturation, with special reference to the elimination of air.

Since the paper was written, an apparatus has been developed by our laboratories, for measuring saturation as a ratio of air to insulation by volume. It consists of an inverted funnel with a graduated-closed-top tube. This is filled with water, placed in a jar of air-free water with a section of cable about an inch thick under it. The jar is then evacuated and the vacuum maintained over night. This results in sucking the air out of the cable and causes it to collect in the tube of the funnel. The vacuum is then broken, causing the air in the funnel to contract to its atmospheric volume. The displacement of the cable is noted, its copper and lead removed, and their displacement noted. The volume of insulation is the difference between the displacement of the cable and that of the combined copper and lead. The saturation is expressed as the ratio by volume of air to insulation. The insulation is then examined under water to make sure that all the air has been removed. There is an error which it seems impossible to eliminate, namely that air is sucked from the strands as well as from the insulation, so that if the interstices between strands are not well filled, the insulation will be debited accordingly. This, however, has not affected the practical usefulness of the device which is now in regular use for control tests.

Mr. Thomas has described experiments which, he says, have enabled him to produce a yellow, waxy substance with numerous voids, merely by exposing mineral oil to a strong electrical field. We have repeated the experiment and obtained the same results. The material, as stated by Mr. Thomas,m elts and has the same electric strength as the original compound. The reason for this is that it is the original compound, the changed appearance after the application of stress being due merely to an emulsification. Mr. Thomas's experiment did not result in producing the material referred to as X in our paper, as this latter cannot be melted. It is neither fusible nor soluble in any solvent available. Chemical analysis shows it to be free of nitrogen and to contain a very small quantity of oxygen. Research work is now under way which, it is hoped, will lead to its chemical identification.

In reply to Mr. Randolph, the tree patterns are readily formed at three-fourths of the short-period breakdown voltage. The addition of rosin-oil compound to mineral-oil compound does not improve the life of the cable.

An important difference between our leakage tree patterns and the steady glow of ionization described by Mr. Kehoe is that the former are matters of visual observation, whereas the existence of the latter is known only by theoretical deduction. Mr. Kehoe says that tree patterns are the result of destructive groping or reaching for the weakest path. We are entirely in accord with this but believe that the weakest path must be along the air pockets because air ionizes at a much lower voltage than oil.

In conclusion, I would take some exception to the general tendency of some of the speakers to assume that American cable manufacturers have not kept up with the general progress of electrical industry. It should be remembered that they have been laboring under a handicap unknown either to other branches of electrical industry or to cable manufacturers in other countries. I refer to the tendency of American cable users to put into their specifications clauses, the undue emphasis of which is entirely irrelevant to the proper performance of the cables but which forces the manufacturers into competition on unessentials rather than allowing them to concentrate their efforts on factors of major importance. Principal among these irrelevant requirements have been excessive flexibility and excessively low dielectric losses. Another requirement of the same character which is now assuming prominence is the so-called ionization test.

If the American manufacturers succeed in making cables which pass American specifications and have characteristics as good as the best European cables, they will have accomplished an infinitely more difficult task than the Europeans have done, and this goal has actually been reached by some of them.

Discussion at Pacific Coast Convention

THE CORONA AS LIGHTNING ARRESTER[1]

(Whitehead)

Pasadena, Cal., October 14, 1924

F. W. Peek, Jr.: In a paper that I presented at Swampscott last year I described some tests in which the variation of the steepness of the wave front and the voltage of a wave were measured as it traveled along a line on which there was considerable corona loss.

It is not necessary to repeat this description here. Briefly, the tests show that the voltage and steepness of the wave rapidly decrease as the wave travels over the line. In this work the effects of choke coils, capacity, open-ended lines, series resistance, etc., were also investigated.

The method of making the tests was simple. Some years ago I found that the sphere gap measured the correct voltage of a transient while the needle indicated a voltage that depended upon the steepness of the wave. The ratio between the needle and sphere voltage was called the impulse ratio. The character of the wave is determined by making measurements by sphere and needle at different parts of the line.

There is no doubt that corona and other losses reduce the voltage of the wave and the steepness of the wave front as it travels over the line.

John C. Damon: Lightning arresters for high voltages have been remarkably expensive and if the transmission line could be the lightning arrester too it apparently would save all of the arrester expense. The trouble is, however, that the transmission line has to be designed to carry the load, to prevent corona from giving too much loss, to give reasonable regulation and to string at such a tension that the towers will not be unduly expensive. These are not independent variables. It has recently become possible to get cable with the outside diameter independent of the cross section of the conductor which will doubtless permit the future design of lines to act as lightning arresters in addition to their other functions.

V. Bush (by letter): The influence of corona on traveling waves is an exceedingly interesting topic, and I greatly appreciate the courage of Dr. Whitehead in making a mathematical attack on the problem. In such a complex phenomenon it is of course necessary to make some limiting assumptions in order to make it possible to formulate the problem at all; and it is hardly just to be too critical of mathematical short cuts when employed in connection with such a difficult matter. Yet I feel that he will agree that a discussion of the nature of his assumptions, and of the logic employed, will be of assistance to those who are intimately interested in this subject.

Dr. Whitehead represents the effect of corona as a constant ohmic leakance. Of course its effect is really cyclic in nature and complicated in many ways. As is so ably considered by Prof. Ryan and Prof. Henline, there is a hysteresis effect, so that corona leakance cannot be expressed even as a discontinuous function of voltage alone; but the function, if it can be formulated, must contain the time also. It has also been considered by some that there is also a cyclic change in capacity due to to corona, but in view of later work, and especially some at the Massachusetts Institute of Technology shortly to be published by Mr. M. F. Gardner, it is certain that this capacity effect is small, if it exists at all. In view of the complexity of the actual phenomena it is good judgment to make the first, admittedly only roughly approximate, formulation of the problem by the assumption used by Dr. Whitehead of a constant corona leakance.

But having made this assumption I cannot understand why the author attempts a new mathematical treatment. The progress of waves on wires, under the assumption of four constant line parameters, was first solved by Heaviside (Electromagnetic Theory, Vol. I, Ch. IV; Vol. II, p. 312, Electrical Papers, Vol. 2). It has received much attention by Poincare, Fleming, and later by Carson and Manneback. The mathematical solution has also been experimentally checked at M. I. T. for the exact case considered.[2]

Moreover this solution of Heaviside's shows clearly that, when the four circuit parameters,—resistance, inductance, capacitance, and leakance,—are assumed constant, a perpendicular wave front of current or voltage remains strictly perpendicular as it propagates at the velocity of light. The wave front is attenuated in magnitude, and there may be distortion of the tail of the wave, but there is no change in perpendicularity at the wave front itself.

Corona may indeed cause the wave front to become non-perpendicular, for corona is not properly represented by a constant leakance; but any mathematical treatment which makes the assumption of four fixed constants should lead to a sustained perpendicular front, or else should substantiate its direct clash with the classic treatment.

The mathematical method of the paper was earlier used by Steinmetz. It represents a traveling wave by a Fourier series, gives physical meaning to the separate terms of this series, and applies to each a modifying factor, due in this case to the effect of corona. This method is bound to lead to error. Having formulated the differential equations of a system on the basis of certain constants, and made a solution, we cannot then introduce the effect of new factors into the separate mathematical terms of this solution without endangering the correctness of our conclusions. We should instead reformulate the differential equations for the conditions obtaining with the new factors introduced as a part of the original premises. Stated in another way, we cannot solve for the Fourier series expressing a traveling wave on a line, and then modify separate terms of our solution in accordance with the effect which leakance would produce on terms of that nature if existing independently, without destroying the dependability of our results.

The danger involved will perhaps be clearer if we carry the method to extremes. The Fourier expression for a rectangular wave of current traveling down a line is a function of distance x and time t, such that it sums up to zero everywhere outside the wave, and to a constant value of current everywhere inside the wave. The separate terms of this series are sinusoids. Suppose we ascribe to each a separate physical existence, and assume that each produces independently its own resistance loss. Since these terms are continuous along the line we are led to the absurd result that we will compute a loss in the wire at points to which the wave has not yet penetrated. The result is exactly the same if we treat a wave of voltage, and the leakance loss.

The paper states that it is a generally accepted belief that a chief danger from lightning disturbances lies in the steepness of wave front. I agree, but not that this is *the* chief danger. The chief dangers are voltage amplitude, and duration of application of voltage due to traveling waves. The steepness of wave front is sometimes of interest, but not often. We usually are concerned with the amount of voltage our terminal apparatus is called upon to sustain, and for how long. We are rarely concerned with how fast it is applied. Steepness of wave front has been overemphasized. We apply the steepest possible wave front, without worry, every time we connect a transformer bank directly to live bus bars. Why be concerned if it is nearly as steep as this when a line intervenes? We do care, though, about amplitude. Corona has its effect on amplitude also of course.

1. Journal A. I. E. E., Vol. XLIII, October, p. 914.

2. Journal A. I. E. E., December, 1923.

J. B. Whitehead: I must apologize for two errors appearing in the paper as printed in the Journal. The first is in the value of the capacity per unit length of line on the second page. The second is the assumption in the computations of a constant value of g, the leakage conductance due to corona. This quantity varies with the frequency. These two errors offset each other in considerable degree. However, the results as indicated in Figs. 1, 2 and 3, require some modification. The general result is that the corrective influence of corona is not so extreme as indicated but still very considerable. Both computations and figures have been corrected for the Transactions.

I regret also that I should have failed to include in the paper reference to the experimental results of Mr. Peek on the attenuation of the voltage pulses on a corona-forming line. Under his reminder I now recall them well. They are strong indications in support of the assumption that corona has value as a lightning arrester.

Professor Bush does me too much honor in suggesting that I have made a mathematical attack on this serious problem. I have not done this. The complexity of the phenomenon, emphasized in the paper and reiterated by Professor Bush, was a sufficient deterrent. The purpose of my paper has been, as clearly indicated, an approximate answer only. While I am well aware of the criticism which has been directed to the use of the Fourier analysis in problems of this character, I have been glad to find at hand in the Steinmetz paper referred to a series of computations which lent themselves so readily to the addition, to other attenuation factors, of that due to corona. Professor Bush appears to have overlooked the fact that the Steinmetz analysis does not assume fixed values of circuit constants. The fact that the analysis takes account of the changes of both resistance and conductance with frequency was one of the reasons why it appealed to me for my present purposes. The method is especially helpful if the conductance is assumed to vary with the frequency as has been done in making the corrections indicated in the first paragraph above.

As for the use of Heaviside's methods, Professor Bush's partiality for them seems to have arisen since the appearance of his very valuable paper on Transmission Line Transients in December 1923, for in that paper he emphasizes clearly the difficulty of using the Heaviside treatment for cases in which the transmission engineer is interested, and also the laborious computations involved in the attainment of numerical results. I suppose he will hardly recommend Heaviside's analysis or any of its extensions for cases in which the resistance and conductance are unknown functions of the frequency. Perhaps the most important thing is that we now have good experimental evidence that the presence of corona on lines not only tends to diminish the gradient of a pulse but also to decrease its maximum value. If, as seems to be true, Steinmetz's method of analysis is open to serious criticism it is obvious that the application of some more correct method to this problem would be a service of great value. I hope that Professor Bush will be led to undertake this, using those methods which seem to him more suitable and convenient.

CORONA LOSSES BETWEEN WIRES AT EXTRA HIGH VOLTAGE[1]

(Harding)

Pasadena, Cal., October 14, 1924

F. W. Peek, Jr.: Prof. Harding has given us some curves up to 500,000 volts on conductors good for operation at 220 kv. or less. His loss measurements under some conditions show a close agreement with the quadratic law over a reasonable range of voltage for the conductors. The difference on several of the conductors is, I believe, due to the fact that sphere gaps were used for voltage measurement. Regarding the divergence at the upper part of the curve where the arc-over voltage is approached, we have sometimes noticed a somewhat similar tendency on measurements that we have made up to one million volts. This has occurred on large conductors at spacing relatively small compared to diameter. It seems to be due to the distortion in the dielectric field that takes place because of the great amount of corona. The ratio of spacing to effective radius becomes small. The flexible corona conductor is distorted and no longer a cylinder. At the voltage when the divergence starts the corona begins to separate into huge cart wheels. These have a shielding effect preventing or lowering the loss between wheels. This does not mean that the quadratic law would not apply for calculation of the loss for million-volt conductors. Larger conductors and greater spacing would be used and the law would hold in the usual way. The tendency to diverge thus seems to apply only to extreme conditions or when spark-over is approached and distortion results.

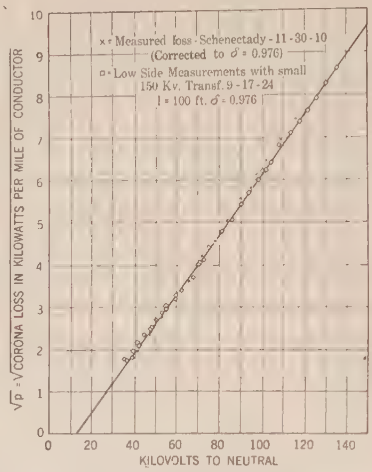


Fig. 1—Corona Loss Curve 0.066 Diameter Galvanized Iron Wire at 162 In. Spacing—60 Cycles

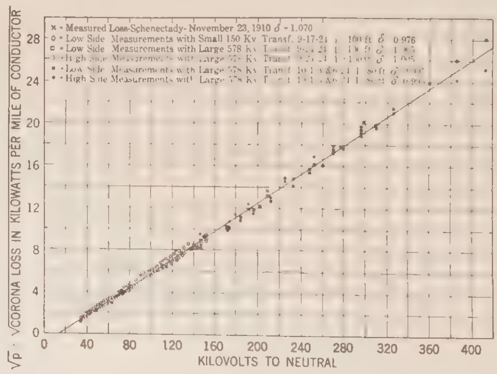


Fig. 2—Corona Loss Curve up to 800-Kv. Between Lines for 0.066 In. Diameter Galvanized Iron Wire at 162 In. Spacing 60 Cycles

We have never found the corona loss to vary from the quadratic as Prof. Harding has. Fig. 1 herewith is plotted from loss measurements made at Schenectady on a long outdoor line in 1910 and from measurements made in the Laboratory in Pittsfield on a short line in 1924. These measurements were made 14 years apart by different men with different apparatus, yet the check is exact. The curve is plotted between volts and the square root of the power because if a straight line results, it proves a quadratic. The range in voltage here is ten times the starting voltage. Measurements made on the same wire in 1924

1. Journal A. I. E. E., Vol. XLIII, October, p. 932.

up to over 1,000,000 volts or 60 times the critical voltage show that the quadratic law holds over this range. This seems to be a remarkably good confirmation of the quadratic law since the 1924 tests were made on a short line and check measurements were made on both high and low sides. The transformer-loss correction at 1,000,000 volts was rather large compared with the corona loss because of the short length of line. A wire with a small radius compared with the spacing was used to give a condition without distortion. Many curves similar to the above, all confirming the quadratic law, were made in 1910 up to about 250 kv.

Fig. 3 shows a similar curve for a cable like the one used by Prof. Harding. The tendency to diverge at about 500 kv. can be noted. The quadratic law is followed up to this point where distortion starts due to the large diameter of the corona. This distortion can be readily observed by visual measurements as noted above.

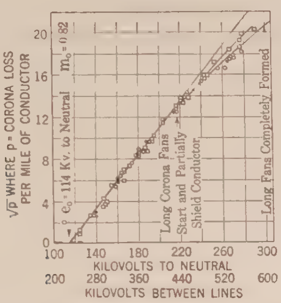


Fig. 3—Corona Loss Curve for 61 Strand, 600,000 Cir Mil Cable at 15 ft. 9½ In. Spacing 60 Cycles, Single-Phase

$r = 0.445$ in.

$\delta = 0.964$

$p = 0.0166\,(e - 114)^2$ kw. per mile of wire.

I do not believe that Prof. Harding can be serious in his statement that 330 kv. could be used on a 500,000 cir. mil conductor. While Prof. Harding's tests are very interesting the data cannot be applied to lines above 220 kv. because the tests were made on small conductors.

In comparing the loss between a single wire and ground with that of one of two wires, the spacing of the single wire to ground should be half the spacing of the two wires and the voltage of the single wire to ground should be half the voltage between the two wires. This would give equivalent stress.

L. P. Ferris: I should like to ask Mr. Harding whether he has taken any account of the change in wave form, which takes place with corona, in calculating the "radius of the equivalent coronal conductor?" I judge not, from the discussion on the sixth and seventh pages of his paper and the formula given in the appendix. Apparently the capacity is assumed to be directly proportional to the charging current per volt, which, of course, it would be if the wave form remained constant. It is well known that corona introduces harmonics as shown in the papers by Prof. Ryan and Mr. Wilkins. The question then naturally arises, how much of the increase in charging current can be accounted for by the increased admittance at the harmonic frequencies of a capacity fixed by the dimensions of the wires themselves and their spacings? There is apparently no doubt that corona is accompanied by a cyclic variation of leakage or capacity or both, but it would be very desirable to have a definite picture of the mechanism of corona and its resulting distortion of wave form. We should then be able to agree on whether or not the capacity is truly increased, and if so, to what extent.

J. S. Carroll: The extraordinary increase in capacitance that Prof. Harding found has been somewhat difficult for me to understand. In some of our tests at Stanford the charging currents were about 10 per cent more than those calculated from the dimensions of the line and the line voltage as given by the voltage coil on the transformer. This bothered me for sometime until I got hold of the oscillogram of the voltage wave on the line. The oscillogram was taken from the Hendrick's coil of the transformer. After the wave had been analysed into its harmonics and these used in computing the line charging currents they were found to be within about 2 per cent of the observed values. The charging currents in the results of Prof. Harding seem to run rather high and the question of wave form, of course, has been previously brought up. These results of Prof. Harding are rather interesting from the standpoint of theory. I think there isn't much doubt that he is well above the economic range of operation, but it is interesting to know the power losses in this region.

I made some computations, using the corona-hysteresis formula that has been mentioned here, and this formula, by the way, fits the condition of the single brush as shown herewith in Fig. 4.

In these cases, until we known more about the conditions, we have to work backward, so to speak, with the formula. It would be a difficult problem to compute the exact capacitances of the arrangement we have there, so I took two points on the observed curve to determine the two unknowns, which would be the critical voltage and capacitance. These values were substituted in the formula and the power loss was calculated for various voltages with the results as shown in the curve of Fig. 4. It is interesting to note that the capacitance of this brush remained constant over a wide range of voltage.

Now, in Prof. Harding's tests. we have a line which is unquestionably being fairly well in corona, but there is some question as to whether it is in full corona. In Mr. Peek's pictures lines about this size are shown at a potential of a million volts and there are still some portions of the line that can be seen, apparently shielded by the brushes. In the use of the hysteresis formula with Prof. Harding's results we used the calculated capacitance as obtained from the dimensions of the line but the calculated values of power loss did not exactly agree with the observed values. However, when this calculated capacitance

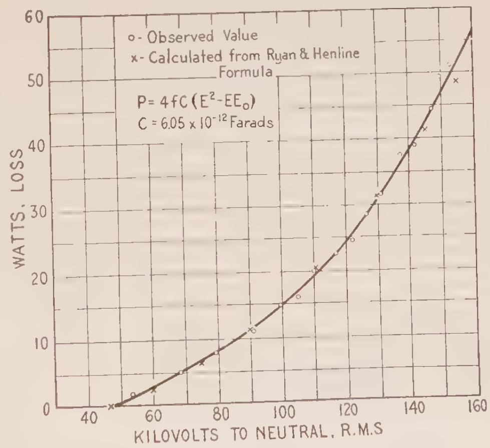


Fig. 4—Single Brush Loss from a Point Extending 3 In. from a 3 In. Sphere

was multiplied by a constant the calculated and observed results were very close. These were only three curves out of the several of Prof. Harding's. With others tried, some fit as closely as these, others not quite so well. (See Fig. 5).

Now, this capacitance term we must think of in a little different way from the ordinary when applied to this formula. As used here it *means that capacitance which is attached to corona and not the capacitance of the conductor computed from its dimensions.* If the conductor is in full corona in every sense of the term then

the field attached to the corona will be the same as that which would be attached to the conductor if no corona were present. In case of the brush formation on the conductor, if those brushes do not cover the whole field then only part of the capacitance of the line as computed from the dimensions should come in use on this formula. If course these curves run right into the x-axis at the critical voltage. That is because Prof. Harding's results begin well above the initial brush formation. Of course, the extreme lower part of these curves is not correct as shown by results in which lower-range instruments were used. At the early brush formation we have a few brushes here and there, in some cases Mr. Wilkins says they are something like 100 ft. apart. It is the capacitance attached to these brushes that we want to consider, and not the full capacitance of the line, when this formula is used. The lower voltages used by Prof. Harding were the higher voltages used in most of the tests made at Stanford. What we are interested in is to find information so that we can predetermine the losses in the economic range. I have done some calculating along this line but the more calculating I do the more I see the need of experimental data and the tests actually made on the lines are extremely valuable in these respects.

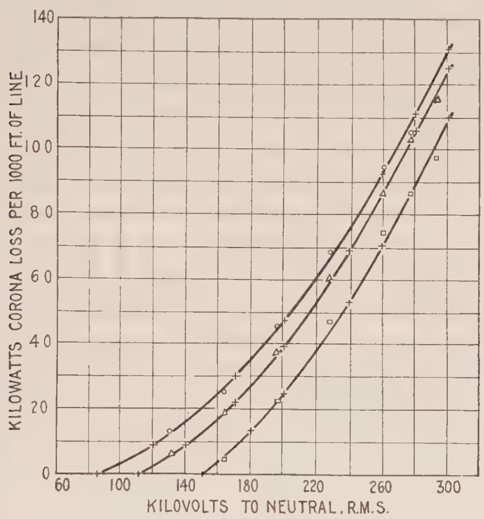


FIG. 5—CURVES OF BRUSH PATTERN IN RELATION TO C AND E_o IN EQUATION

$P = 4 f c (E^2 - E_o E)$, Ryan and Henline.

Using data given by Prof. C. F. Harding in his Pasadena Paper.

Curve	⊙	△	⊡	X
Conductor	2/0	4/0	500.000 cir mils.	Calculated from Henline Formula Using K C instead of C
Diameter	0.447 in.	0.564 in.	0.904 in.	
Spacing	18 ft.	18 ft.	18 ft.	
Capacity M. F. per 1000 ft.	0.00246	0.00255	0.00275	
K	0.85	0.90	0.93	

Just one other word in regard to this capacitance. In the laboratory tests inside where we fixed up the rods with points on them, and water drops just where we wanted them, in other words, where the brush formation was fixed, the corona-hysteresis formula fits the results exactly, just as it did in the case of the single brush, but when we come up to the order of a polished rod where the brush formation is not fixed, then we have trouble. I might say that in one case I tried a mathematical experiment similar to what Mr. Peek did, splitting the curve up into two component parts, you might say, with two different values of capacitance and two different critical voltages. I assumed we had a certain set of brushes at a certain critical voltage and that would have, of course, a certain capacitance; then, later on there was another set of brushes starting in with a higher critical voltage and an added capacitance. It came out very well.

C. Francis Harding: In closing the discussion of this paper, to which contributions of interest have been made by Messrs. F. W. Peek, Jr., L. P. Ferris and J. S. Carroll, it seems necessary again to emphasize the fact that the corona losses presented in the paper are actual, accurate results of tests under standard conditions of line construction and not extrapolations from empirical laboratory data. It is recognized by the author, as stated in his paper, that changes in both the design and construction of transmission lines for voltages above 220 kv. will be found necessary in order to avoid excessive corona losses, but the most practical way to determine the obstacles to be avoided in such designs is to determine the actual losses and other unknown phenomena resulting from higher voltages impressed upon present standard line construction.

The "difference on several conductors . . . . due to the fact that sphere gaps were used for voltage measurement" suggested by Mr. Peek for the variation between values presented in the paper from theoretical calculated results has not been explained sufficiently by reference to the use of the sphere-gap, since the latter is recognized as the standard method of voltage measurement.

That the divergence between test and calculated corona losses, at the extra high voltages, may be due to distortion of the dielectric field, as suggested by Mr. Peek, is quite probable. This cause was mentioned on page 937 of the paper when, in reference to Figs. 14 and 15, it was found that the capacitance and diameter of the "equivalent coronal conductor" were not only unexpectedly large at very high voltages, but were erratic in behaviour at critical voltages and spacings. It is significant that these results have been confirmed by Mr. Peek in Fig. 3 within the range of 440 and 600 kv. between lines, although the size and spacing of conductors have not been given. The results submitted by Mr. Peek in Fig. 1 of his discussion represent values at much lower voltages, with no indication of the sizes or spacings of wires tested. The losses of Fig. 2, which are not referred to directly in his discussion and for which no cable sizes or spacings are listed, apparently indicate a considerable departure from the straight line determining the quadratic law if the curve be drawn through the points indicated as "High Side Measurements." The "Low-side Measurements" of net losses are necessarily made less accurately, although the methods of calculation and the conditions of test adopted are not indicated in his discussion. The conclusion seems to be warranted therefore, that between 440 and 600 kv. the divergence of such net losses from the calculated results may be considerable, if the conditions of line construction are such as to permit the formation of considerable corona.

With regard to the use of 500,000 cir. mil. conductor at 330 kv., no statement in the paper will be found to the effect that "330 kv. could be used on a 500,000 cir. mil. conductor" as incorrectly quoted by Mr. Peek. Losses between *two such cables* at spacings of from 30 to 34 ft. are shown in Fig. 8 of the paper to be "moderate" as compared with smaller cables and higher voltages, but the determination from test values of a loss of 107.0 kw. per mile of three-phase, three-conductor circuit of 500,000 cir. mil. cables at twenty-six foot spacing is stated on page 935 to be "*obviously excessive and would, therefore, involve a change of design for a line to operate efficiently at such a voltage.*" Although it is probable that larger conductors will be used for voltages above 220 kv. when such lines are constructed, the possibility of increasing spacings between wires and the reduction of clearances to ground in some sparsely settled districts may be found to be a more economical means of reducing corona losses to an efficient minimum than by providing all of the adjustment by means of increased cable sizes.

No high-voltage transmission lines at present maintain the

clearances between cables and ground equal to one half the spacing between the cables. It is recognized, as pointed out by Mr. Peek, that such an arrangement would provide equivalent electrical stresses. The test results of Figs. 17 and 18 were inserted in the paper in order to illustrate the saving in corona losses which may be found possible in the future by increasing spacings between cables by installing each cable or two cables of the same potential of a multiple circuit line upon individual relatively low towers, installed transversely upon the right-of-way at relatively wide spacings as compared with the height of such cables above ground.

In reply to Mr. Ferris concerning wave-form, it may be said that the calculations of capacity and the resultant "radius of the equivalent corona conductor" were made upon the basis of the sine wave having a maximum voltage established by the sphere-gap calibration. Although there is no doubt that harmonics are introduced by the corona formation upon such a line, particularly under partial and variable corona conditions, yet previous results reported to the Institute[1] by the author upon another experimental transmission line were determined from the oscillograms of both voltage and current, which seemed to indicate only very slight wave distortion at the higher power factors resulting from the very high voltages and consequent large corona losses. However, some of the seemingly erratic capacity variations at critical voltages noted in Fig. 14 may possibly be accounted for later upon the theory of distorted wave form. It is hoped that further studies may be made upon the effects of wave form upon this line.

The conclusion expressed by Mr. Carroll confirming the "need of experimental data and the tests actually made on the lines" is very pertinent, as it is believed that only the results of actual trials of extra high voltages upon lines duplicating future operating conditions with proposed new methods and designs for corona loss reduction will prove conclusively what the most economical, efficient, safe and entirely satisfactory line construction is to be for 330 kv. and above.

INTERCONNECTION OF POWER SYSTEMS IN THE SOUTHEASTERN STATES

(Mitchell)

Pasadena, Cal., October 14, 1924

P. H. Thomas: Mr. Mitchell's paper is particularly timely since it indicates not only the most advanced point to which widespread interconnection of large systems has progressed in actual practice, but points out the probable solution of some of the problems now being faced in the further extension of interchange.

I have in mind such matters as voltage control at individual stations on a tie line, when the direction of energy flow changes, the proper distribution of true energy between plants, with changes of load and other conditions throughout the 24 hours and the placing and control of wattless. These features would involve no difficulties if the systems could be laid out new, with operation interconnected in view, but may cause very serious trouble if large systems are merely interconnected without proper study of their characteristics.

The scheme of Mr. James utilizing a curve connecting the "peak kw-hr." and the "base kw." for assigning the position of the generating units is most ingenious and useful. I have used a similar curve built up by integrating the kw-hr. shown by the load curve below any given kw. generating capacity. I have extended it to distinguish between minimum stream flow hydro power and pondage power and to make assignments to individual stations. It is a most useful analysis.

There are two principal points to which I will call attention.

First—In any large interconnection, even where there is no dominating water power plant or single steam station of supreme importance, there will be a considerable amount of installation in tie lines, condensers and power stations in which the interest of the whole will not be the the same as that of some of the individuals. For example a tie line might be of great advantage to an outlying system but of small value to the system in whose territory it lies, or the construction of a line by a different route or at a higher voltage might be of great future importance to the group as a whole but of no immediate value to the company operating in the territory to be crossed.

The conclusion to be drawn is that there will apparently be a great advantage in creating a common entity or organization, controlled by and working for the interest of the whole, which could properly undertake work that it would not be fair to ask any one company to undertake. The existence of such a unity would greatly facilitate interchange contracts for power. Indeed, it is difficult to see how the full benefit of interconnection can ever be established otherwise.

Second: My second point is to emphasize the necessity for looking ahead and planning a complete skeleton system for the future covering the full zone in conformity with which new installations can be made. Without this there will inevitably be much waste. For example a tie line laid out for an immediate interchange may be directly overbuilt by a higher voltage line a few years later.

If it turns out that single-circuit lines as proposed in my paper presented at the Birmingham convention are of advantage, the building of a two-circuit line may later require the addition of another line to reach some parallel point, which might have been reached by separating the original two-circuit line and running the circuits by different routes.

Again: The divided conductor has a very great theoretical advantage in a widespread interconnected system, both in increasing the capacity to balance lagging current and in reducing inductance to facilitate tie-line interchange of current. If this is to prove the best construction, the sooner this is determined the better.

The full importance of lagging current and wattless component is not generally realized. As long as the lagging could be cared for by running the generator at low power factor and lines were short, wattless cost little. But with very long lines, wattless must be largely eliminated at the receiving end and this must often be done by installing new machinery to carry wattless kv-a.—a very expensive process. Therefore, the gain in charging current by dividing the line conductor may be more important in the future than it has been in the past.

It is not unlikely that very large sums of money may be saved in the next 15 years by proper planning ahead for the interconnection and this is particularly true in the zone treated by Mr. Mitchell.

LARGE STEAM TURBINE GENERATORS[1]

(Foster, Freiburghouse and Savage)

Pasadena, Cal., October 15, 1924

A. M. Rossman: The built-up rotor construction which Mr. Foster describes is interesting to us because of an experience which we have had within the last two or three months with a solid forged rotor.

A machine had been operating down in Texas for eight or ten years. The rotor winding had gone bad and the rotor was sent to the factory for rewinding. The factory examined it and found a crack in the rotor which extended two-thirds around the circumference, and rendered it unfit for going back into service. We then split it and found that the only good metal left consisted of a skin of metal about 1/8 in. or 1/4 in. thick on one side and, on the other side, a small wedge 2 in. or 3 in. in thickness extending from the center to the outer surface. How that machine

1. "*Corona Losses between Wires at High Voltages I*" by C. Francis Harding, Transactions, A. I. E. E., Vol. XXXI, Part I, p. 1036.

2. Journal, A. I. E. E. Vol. XLIII, December, p. 1150.

1. Journal A. I. E. E., Vol. XLIII, October, p. 923.

continued to operate with the rotor in that condition is a mystery.

Going into the history of this rotor we discovered that it had been made in Germany and shipped to this country just before the war began. It had an exploring hole drilled from end to end and the factory records showed that a small crack from shrinkage had been detected. They did not, at that time, attach the significance to that small crack that they should have. Now, I understand, such a forging would be rejected. In the built-up rotor described by Mr. Foster such a crack could not easily develop.

Another point is this question of low temperatures. We are very glad, indeed, to see progress made toward cutting down the high temperatures. The earlier machines used to give considerable difficulty. The copper would expand when it was hot and shrink when it was cold, and before we knew it, the insulation had separated from the copper and was bowing out in the ventilation slots; the next thing we had a break-down and the machine would have to be rewound. Low temperature means low expansion and a lessening of mechanical troubles.

C. M. Gilt: The maximum size of turbo-generators has increased in a series of steps with periods of several years intervening in which the size has remained fairly constant. Recently another step has been taken, beginning with the 62,500 kv-a. units for Brooklyn and followed by machines of even larger capacity.

The amount of power developed by, and the money invested in, one of these large units is so great that the problem of adequately protecting it against damage, and of limiting the extent of the damage should a failure occur, is presented with increased force. The older practice of tying generators to the bus without any automatic protection against internal failure has been replaced by a scheme of differential protection of the windings. The method of balancing one end of each phase winding against the other is serviceable in case of a phase-to-phase short circuit, or phase-to ground when the unit is on a grounded system, but will not operate on a turn-to-turn short circuit within the same winding until the damage has spread far enough to develop into a ground or a phase-to-phase short-circuit.

As a further protection the groups of parallel windings within the same phase windings of the Brooklyn machines have been balanced against each other with cross-connected current transformers. This method of protection loses its sensitivity when the number of turns per phase is large for the circulating current sent around the closed loop by the unbalance of the voltage in the parallel paths is a small portion of the total current of each path.

We are considering a somewhat different method of balancing the windings of one of the machines on the system and from such studies as have been made it appears to have some advantages. The method consists in tying together the parallel windings at equipotential points at approximately the middle of the winding and inserting a current transformer and relay in the tie. Normally no current should flow across this tie and the current transformer can, therefore, be built of a size to give the best relay operation. In case of a turn-to-turn short circuit, a ground or a phase-to-phase short circuit occurring in the windings between the ends where they are joined together, a current will flow across the mid-point connection and cause relay operation. The advantage of this method over the scheme of balancing the windings with cross-connected current transformers lies in the fact that the relay operates directly on the cross flow of current and not on a small difference between two large currents. The disadvantage lies in the additional number of leads that must be brought out of the machine and the taps made at the mid-points. The additional leads brought out need not be full capacity, but built only to withstand possible short-circuit currents. While the scheme appears to be selective, there may be difficulty in picking out points on some machines as actually built so that the cross flow of current under all conditions of load and external short circuit will be enough smaller than that which would occur in case of a turn-to-turn short circuit to give positively selective relaying. This difficulty, however, applies with equal force to the other method of balancing.

We agree with the authors of the paper in favoring a closed system of ventilation for these large machines. Not only is it more effective thanan air washer in keeping the machine clean, but we believe has also a decided advantage in case of a fire. The oxygen within such a system will not sustain combustion very long. In addition a gaseous extinguisher, such as carbon dioxide, can be used effectively within a confined space.

We are naturally keenly interested in the development of these large machines, their protection and operation. We believe that there is a real place for them on the larger systems and hope to see them perform creditably.

E. H. Freiburghouse: While it is possible, as Mr. Rossman points out, to inspect thoroughly the cylindrical body and stub ends of a rotor such as has been employed in this 62,500-kv-a. generator at Brooklyn, nevertheless, very rigid sensitive tests are made by which forging faults may be detected and located throughout the interior of the one-piece solid forged rotors.

It has been our practice for many years to use a solid forged steel rotating element having radial slots machined in it to receive the windings. The reliability of the solid forged rotor has been demonstrated by the successful operation of over 1000 units ranging in capacity from 2500 to 62,500 kv-a. and rotative speeds from 1200 to 3600 rev. per min.

No failures chargeable directly or indirectly to forging faults have occurred during operation either in the factory or in service. This is also true of the nickel-steel forged rings which support the end portions of the rotor winding.

Three inspections are made of the interior of the forging, the first being at the forge shop.

The number of rotor forgings rejected from all causes has been less than 2 per cent of the total number received to date.

The scheme of protection mentioned by Mr. Gilt for obtaining protection against internal faults, such as short-circuited turns, has been considered and seems to have desirable features, but to the writer's knowledge has never been applied.

HEATING OF LARGE STEEL-CORED ALUMINUM CONDUCTORS[1] (Wood)

Pasadena, Cal., October 15, 1924

A. M. Rossman: I was shown recently some results of a heating test of a cable passing through a clamp. The cable was 300,000 cir. mil copper cable and the clamp was a drop forging. In that case the current was raised to such a value as to give an appreciable heating of the conductor. The clamp showed a temperature several degrees higher than the conductor. This is contrary to the results which Mr. Wood obtained.

The question of the effect of direct sunlight in raising the temperature of a large conductor and increasing the sag has a close reference to the problem investigated by Mr. Wood. If the measurements were made indoors under a skylight, the effect of wind would be eliminated. If they were made out-doors, the error due to reflection by the skylight would be removed. The results, though approximate, would give additional data for calculating the maximum sag.

The question of the best size of steel core is one which could be investigated with the apparatus used by Mr. Wood, if samples of cable were obtained having different sizes of steel core but the same cross section of aluminum or copper.

Among the advantages of a larger steel core are: first, reduction of corona loss; second, reduction in skin effect due to the aluminum or copper taking the shape of a thinner tube; third, reduction in resistance due to larger cooling surface and lower temperature, and fourth, reduction in resistance due to the current carried by the steel core, which, although a small percentage, is not negligible, but amounts to about 2 per cent.

1. Journal A. I. E. E., Vol. XLIII, November, p. 1021.

These advantages are all equivalent to increasing the conductivity of the aluminum or the copper. They should be balanced against the disadvantages due to the larger steel core, of greater cost, weight, ice load and wind load.

Such a comparison might result in the use of a core of low-grade steel for a large copper transmission cable. A core of low-priced steel has usually better conductivity than one of high-grade steel, for alternating current, though not always for direct current.

If accurate means are not available for measuring the watts loss with alternating current, each sample of cable could be calibrated by measuring its final temperature rise when direct current is flowing, for which case the watts loss can be accurately measured. The temperature rise by thermo-couple can also be very accurately measured, as is shown by the test readings plotted on the curves in Mr. Wood's paper. Curves would be drawn for each sample showing the continuous temperature rise plotted against watts loss. Then, when alternating current is flowing, the watts loss would be deduced from the temperature rise, and the effect of the steel core on the conductivity of the cable for alternating current could be judged.

For example, if 400 amperes, alternating current, in a 600,000 cir. mil copper cable without a core produced a temperature rise which gave 107 watts in a certain length, from the calibration curve of that sample, and if the same current in a cable with 600,000 cir. mils of copper and a steel core produced a temperature rise which gave 100 watts on the corresponding curve, then the core had increased the conductivity 7 per cent, by reducing skin effect, by lowering the temperature and by adding the conductivity of the core itself. This total percentage increase in conductivity due to the core might be greater than the percentage increase in cost caused by the core, and there would be the added advantage, of probably more importance still, that the corona loss would be decreased.

In making such a test, the samples might be connected in series, so that there would be no doubt that they carried equal currents. Such a test, like many other measurements in physics, could well be made in a room in which a thermostat controls electric heaters of sufficient size to hold the room temperature exactly constant, which is a very easy matter to arrange except in hot weather.

THE POSSIBILITIES OF FLASH-OVERS[1] (Austin)

Pasadena, Cal., October 15, 1924

F. W. Peek, Jr.: If I understood Mr. Austin correctly, it is his belief that insulators on transmission lines may arc-over at very much reduced voltages due to some localized high-frequency phenomena starting at a corona brush.

Any discussion on high frequency is valueless unless the type of high frequency is defined very accurately. Careful and accurate researches have been made on the arc-over voltage of insulators and gaps for different kinds of high frequency. The results are as follows:

The arc-over voltage for lightning, transients produced by switching or arcing grounds, or any damped oscillations of low train frequency, *is always higher than the 60-cycle arc-over voltage.* If there is corona during the discharge a still higher voltage is required to cause arc over. It is higher because of the time lag.

The arc-over voltage for undamped high frequency, or for damped high-frequency oscillations where the train frequency is above 1000 trains per second, is lower than the 60-cycle arc-over. The arc-over voltage is lower because the ionization persists from cycle to cycle or from train to train. In order to reduce the voltage it is necessary to apply the undamped oscillation for an appreciable time. With this type of high frequency, I may term it radio frequency, many spectacular results are possible on comparatively short wires in the laboratory; these results may be produced locally by tuning and by the thermal effect. When corona is started at a given point a hot brush is formed and persists. If the point is covered by solid insulation the brush will start elsewhere. In my early work on this type of high frequency described in my book I called these brushes electric needles. Mr. Austin has termed the phenomena "pluming." Arc-over may take place at half the 60-cycle arc-over. Although Mr. Austin does not give any generator data from which the type of high frequency used in his experiments can be determined, the results show that it was without doubt of the radio type. *The experiments are interesting but do not apply to transmission lines. Such disturbances have never been observed and cannot exist on transmission lines.*

Corona loss increases directly with the frequency. To energize even a single mile of single line similar to the 220-kv. line of the Southern California Edison Company at 20,000 cycles at 300 kv. above ground, or half the 60-cycle arc-over voltage, would require about 250,000 kw. This would have to be generated and supplied at 20,000 cycles. Where would it come from? Furthermore, any high frequency on a transmission line requires an arc. It is thus secondary and does not account for the initial break.

Although there is no theoretical or other basis to believe that such disturbances as Mr. Austin describes can exist on a line, I have deliberately tried to produce them by making arcs and corona on lines of small loss and high concentration of capacity but without success.

I have tested the shield described by Mr. Austin and find that its characteristics are very similar to those of the bare horn for any lightning or arcing-ground disturbances that can appear on transmission lines. In my tests the insulator caps were frequently punctured by both lightning and 60-cycle discharges. The grading effect was small. I could find nothing to commend its use over the bare horn. On the other hand the ring shield has a decided grading effect and good characteristics for lightning and arcing-ground disturbances. Incidentally it is interesting that the ring shield is used by the Radio Corporation for radio-frequency insulators.

I would like to ask Mr. Austin how long the line is in Figs. 7 and 8. I should judge that it could not have been over one or two hundred feet. I would also ask him the type and power rating of the radio generator used in the test.

While I could not cause insulation arc-over by high-frequency voltages generated by an arcing ground in a 220-kv. line excited at normal voltage of 127 kv. to ground, I could readily cause arc-over by dirt.

The formation of dew on a thoroughly dirty string would cause flashover. A wet thread falling across the string would cause flashover. A small tube corked at one end and filled with two ounces of water was placed above the string. When the cork was pulled by means of a cord a small stream of water rushed past the insulators and immediately caused flashover when the line was excited at 127 kv. to ground. This test was suggested by the engineers of the Southern California Edison Company to simulate the effects of birds roosting above the center string. We can all understand these simple causes of arc- over. However, there always seems to be a tendency to go to the mysterious to explain trouble. The term "high frequency" was generally misused a few years ago to account for the then prevailing insulator failures now recognized to have been due to cracking.

Therefore the various mechanical types of failure due to dirt accumulations are the most serious causes of trouble. In certain parts of the country there is lightning. Fortunately, the arc-over voltage for lightning and all other transients that can occur on transmission lines is very much higher than for 60 cycles.

As to the radio type discussed by Mr. Austin, it cannot exist at any appreciable voltage because of the enormous losses. Sixth-cycle voltage cannot convert itself automatically into high-frequency voltage. The conversion can occur only through

1. Journal A. I. E. E., Vol. XLIII, December, p. 1146.

powerful arcs if the energy is appreciable. The initial breakdown or arc must start in some other way. It cannot isolate itself to any one section of a transmission conductor.

F. G. Baum: I am going to try to separate the insulator problem into its several elements to see if we can't arrive at some way of eliminating some of the confusion that seems to be prevalent.

In the first place we have to assume, in this insulation problem, that we have a mechanical structure that is as reliable as the line itself. That is, that the insulators will not have puncture and failure through mechanical causes whether they start from electrical sources or not. In other words, we want the line to remain in place whether there is an insulator flashover or not, but we do not want the insulators to puncture or to deteriorate mechanically and let the line wire down. The present circuit breakers protect the insulators from damage generally during "flash overs." We will start with that assumption.

Suppose we have two electrodes in a horizontal position in space, call them spheres, and apply potential between them, and we know we get a very high arc-over value. Suppose it rains between those two electrodes, the insulating value is practically not reduced. That is, for practical purposes the insulation is very high and practically at its original value. The first point then I want to make is that so long as we have this discontinuity in the water drops we have high insulation. Remember that! *So long as we have discontinuity in the water drops we have high insulation.*

Suppose we put a porcelain tube between those two electrodes we have the same conditions now except that we have the rain falling on the tube; that tube may be 2 or 3 in. in diameter. So long as those water drops are discontinuous on that tube I have high insulation, but let the rain continue until the water drops collect on the bottom, as a practically continuous film, and the insulation goes down, not merely a few per cent, but *only a few per cent of the insulation is left.* Probably it drops to 5 per cent or sometimes less, depending on the electrodes and on the amount of rain. If you watch a tube of that kind you will see rings of fire all along the tube, those rings being short-circuited at the bottom by the water drops. What can we do about it? We must get rid of the short circuits due to the water drops, so we simply place on the tube a series of flanges. In other words, in place of having a tube we make a tube with a series of flanges on it. Now the water drops are discontinuous and we have high insulation again. In the first place I have removed the continuity of water due to the drops forming at the bottom of the porcelain tube. I have also increased the leakage length due to the fact that I have added to or increased the leakage path. I may, in that way, increase the insulation very materially.

Suppose I take those same two electrodes and place them in a vertical position. If it rains we have high insulation. But place a porcelain tube between those two electrodes and allow the rain to come on the tube surface and you will find a water film; the water film in this case will be continuous vertically, and you will find a film of fire running down the tube and the insulation will break down at less voltage than the tube did when it was placed horizontally.

What can I do in this case? Something similar to what I did before. Place flanges on it. *I must break up the continuity of the water film on the surface of that insulator before I can get insulation.* I then increase the leakage length by an amount added on the top and on the bottom surfaces. If I make this the top one large enough the top surface becomes the umbrella, which is the top of Professor Smith's insulator. That is, I have a rain deflector; the bottom is still insulated. If I vary the diameter as I go down I will improve conditions—and I am glad to see that Mr. Austin is coming to that point. If I alternate large flanges with small flanges I have a means of breaking up, in a natural way, the continuity of the water on the surface of my insulating members—and that is what we must do to have high insulation.

Unfortunately, we cannot make out of porcelain or glass a long enough single piece in order that we may have the distance that we require for other reasons than pure leakage, so I have to take this insulator and cut it up into pieces. At the present time each one of these is cut up into pieces with your disk unit; and in Professor Smith's insulator he proposes to have only two units in between, giving a semi-housed insulating member in between, and it does give some very remarkable results.

When the insulator problem first came to us some twenty-five years ago, it was actually seriously proposed to house-in the top of every tower, because then we didn't have any porcelain insulators, which is somewhat on the line Professor Smith is proposing. He houses in between two metallic electrodes his insulating members and he is getting some good results. The weakness of this unit seems to be in the leakage surface. I would say if a straight member is good in between these two electrodes, then it ought to be improved if we can improve the length of that member by adding flanges.

Our present insulator string is made up of a series of cap-and-pin units. We all know that the effect is that the lower part of the string tends to take a large part of the potential and the upper part tends to take a smaller. It has been proposed, then, to place a ring part-way up on the string, a shield in order to redistribute that stress, to a certain extent, and that is a material help if we have had plenty of room outdoors to work with this reduction of the clearance vertical to the tower. That is a very good method of improving the action of string. I do not think it is as good as if we could increase the size and have half as many units, and get down to a string with five or six units. Professor Smith proposed two units; he is not bothered with the potential distribution.

When we had the problem of insulation of the Pit River line before us we started testing with the ring shield. That was a development of Mr. Peek's, as you all know. We objected to the large shield around the insulator string reducing the clearance, all of which cost money; also because of the fact that limbs, or other objects, or the action of birds may be a means of short circuiting between this ring and the string. We tried to find a way of first reducing the size of the shield, and, assuming that the line wire would act as a shield in that direction, we proposed a shield consisting of two vertical horns. That does help the distribution, not as much as the ring, but it does help and it removes a part of the streamer, and for mechanical reasons it has some value.

While making tests on high voltage the streamers from the horn tips were very concentrated, and in the laboratory at Stanford University I proposed that we place an insulator over the metal horn. As far as I know that was the first time that, what Mr. Austin called an "insulated control," was used. For high frequencies of 50,000 or 100,000 cycles it does suppress the streamer running from the horn. But we finally came to the conclusion that any such addition as that seemed to be a sort of a make-shift and if we had to depend on an insulator over each one of the horns to make the line operate, and we knew that some of them might puncture at sometime and might be causing trouble and there would be some difficulty in finding it. There is quite a concentration of potential at the horn when you have a flashover.

We finally decided not to use that sort of a shield, but to use a smaller disk shield at the bottom of the string to distribute the stress somewhat; but the matter was also decided on for another reason which neither of these other two methods of shielding seemed to meet. If rain is falling on the insulator string and the insulator string is dirty, and you watch the gradual wetting of the insulator string, you will find the top and the bottom of all the units become wet very quickly, *with the exception of the bottom of the lower unit*; that remains dry and you will find then a big arc running from the pin to the outer edge of that unit. In order to prevent that you must have below this lower unit what we call a splash surface which will make the lower unit act the same as the other units. So we placed under the lower unit a

shield so that when the rain comes the splash comes on all the surfaces alike. And in actual tests, when the lower unit was flashing over, by squirting water under the lower unit, the flashover and the insulating value of the string was increased quite materially. In other words, there was a more uniform distribution of stress.

Like Mr. Peek, I wasn't quite sure just what Mr. Austin proposed to do for our power systems. He seems to think that there is a great deal that is not right, but just what his method is, and what he would do to remedy the trouble was not quite clear to me. There is a great deal that is right about the power transmission systems and very little that is wrong. We must meet the insulation problem for the worst conditions that we can conceive, then we need not bother about the intermediate stages.

I have been hearing about high frequency and high voltage on our transmission lines for many years. We have spent months and months of study, much time and much money to try to find this illusive high frequency and high voltage. So far we have not been able to find anything of the kind. We have come to the conclusion that high frequency, like sea serpents and ghosts, is very much exaggerated.

We have made setups on the Pacific Gas & Electric Company system—I am anticipating something I am going to tell you a year from now—in which we had several hundred miles of line in operation and we got the results at the beginning and the end of that series. We have switched the lines out; we deliberately short circuited the 220,000-volt 200-mile line—we short circuited it not once, but repeatedly, to determine what happens in the short circuit; when the short circuit is produced, by a simple mechanical motion. The short circuit results in a given electrical action exactly the same in every case; there is no difference.

My general opinion is that not high frequency and not high voltage is causing the trouble, but it is a lowering of the line insulating air near the tower and a lowering of surface-leakage resistance; it is either insulation of the surface of the insulator, or the lowering of the air insulation in a way which we have not quite found out.

W. A. Hillebrand: The flux control, as developed by Mr. Austin, is simply a shielded or a screened electrode embodying the principle or device that has been used a great many times, or which has been in use for a great many years. It has been used for a bus support; it has been used in high-voltage post-type insulators; it has been used in radio insulators for a number of years, so that it is merely a logical development preceding out of a very large amount of experience which promised to indicate about what we could expect in the way of results.

Fundamentally, the idea is simple: That is, to rob the exposed metal parts of their excessive gradient. That is accomplished by projecting the conductor into a favorable portion of the field, insulating that conductor so that you can not get a streamer or power arc therefrom, thereby shielding the part which must necessarily be exposed.

Now, this arrangement has some definite value at 60 cycles. It has, as tests have shown, a very marked effect in raising the flashover value against high frequency, either sustained or damped waves. It should have a corresponding value in insulating against transient steep wave fronts and traveling waves. Due to the shielding effect it should have a value in reducing the small arcs which are now becoming troublesome from the interference with radio and in the suppression of which the engineer will probably have to spend real money. These are factors which have never been of importance. but they must be taken into account today. Instead of a bare horn, or conductor, or a ring for birds to drop excrement on, and for grass, weeds, strings, etc., you have an insulator.

This device should function simply for the reason that the fundamental principle it works on reduces the gradient about the exposed metal parts and offers an expedient which will find a definite application in the insulation of transmission lines, both on the line and in the substations.

H. Michener: In considering this paper of Mr. Austin's it should be borne in mind that it is dealing with high frequencies rather than with 60 cycles. One statement in particular in regard to the flashover voltage of the string of insulators shown in Fig. 11 should be noted. This is a very complicated arrangement of insulators of different styles but the flashover voltage will be about the same as that of the string of standard suspension insulators without shielding shown at A, Fig. 1. He states that the flashover voltage of the string with his type of shielding will be 50 per cent higher than that of the string shown in Fig. 11. Reference to Fig. 1 shows that this statement is true only at frequencies above about 14,000 cycles. Following the curves back to 60 cycles, which is practically the zero frequency line, they show only a 10 per cent difference in the flashover voltages of the unshielded string and the string with the Austin-type shields.

I believe that most of us who are operating 220,000-volt lines will agree that our interest in Fig. 1 ends with the first vertical line, *i. e.* with the 60-cycle frequency.

R. J. C. Wood: We have gone to a lot of trouble and expense, as has the Pacific Gas and Electric Company, in the effort to discover if there were any of these mysterious things, happenings, which have been suggested, that might occur. We went all over the line looking for resonances of the third and fifth harmonic, and other harmonics, and could not find any. We went over the line looking for high voltages. The Westinghouse Company has helped us recently with an instrument, the klydonograph, that indicates, photographically, if there is a high voltage on the line. We do not find any rises of voltage exceeding double normal voltage and I think that we may say that 99 per cent of those are directly due to switching. The few that apparently are not due to switching, that we can't directly check in with switching, may be difficult of assignment to a cause due to the fact that the clocks of the klydonographs do not run absolutely correctly and the time of any disturbance is known only between certain limits.

These photographs I spoke of tell us whether the surge is a single-fronted wave or whether it is an alternating performance. I think that if any of these high-frequency oscillatory effects were there in magnitude the plate would show them. There is nothing of a magnitude sufficient to explain a flashover, either unidirectional or of an alternating nature.

There is a picture here in Mr. Austin's paper, Fig. 10, showing a string out of about nine different varieties of insulators. I think nine varieties are too many.

When we started out on this problem of insulating the Big Creek line we had in mind the idea, if possible, of using one kind of standard insulator to facilitate our warehouse transportation and maintenance facilities. Then, when replacements are necessary one kind of an insulator will take care of everything.

In that same Fig. 10, Mr. Austin suggests fitting the insulator to the gradient, rather than changing the gradient to fit the insulator. I don't think the result is very different and certainly, as I have already suggested, fitting the gradient to the insulator makes a much simpler problem for the maintenance and repair men.

A. O. Austin: As I stated, the conclusions depend largely upon the numerical values involved. The paper deals primarily with the air break-down between conductors and tower or ground and the means for preventing same. It is a difficult matter to obtain records of disturbances on a transmission system extending over a great many hundred miles and which may exist for an instant only, but lack of records of these disturbances does not necessarily mean that they do not exist. With improvements in recording apparatus, our knowledge as to the existence of transients or disturbances on the system will be greatly increased during the next few years.

It is claimed that an insulating system which shows up to advantage on any combination of high frequency, impact or normal frequency must include all of the possible voltage condi-

tions existing on the transmission system. Therefore it should show up to advantage when applied to a transmission system.

If an insulating system is deficient as to performance under impact, damped wave trains, superimposed high frequency or a few cycles approximating a continuous wave or for normal frequency, the performance of the insulator or the system may be limited to the extent of this deficiency.

A properly designed insulated control or insulated control and conductor cages will increase the flashover voltage over the insulator string or between conductor and ground for the following conditions:

1. For an impact.
2. For normal frequency.
3. For a damped wave train.
4. For a continuous wave train.
5. For any combination of the above.

In addition to increasing the flashover voltage for the above conditions, the system as outlined in the paper will improve the string gradient, although this may not be a determining factor in the performance.

With the insulated control the effective striking distance to ground need not be decreased which is a very important point to remember where flashovers occur due to existing limited clearances and in the construction of new lines where increased tower clearance greatly increases the cost of the structure.

Since the system as outlined will improve the performance of the insulator string or the conductor for any of the above conditions, it is reasonable to assume that its use on the transmission system will tend to raise the flashover voltage and permit the damping out of disturbances without their causing flashovers. There is much evidence to indicate that the energy necessary to cause a flashover is exceedingly small and there is further evidence which would indicate that flashovers may be started by rather small voltage rises.

In answering Mr. Peek, I may say that it has been assumed that extremely high voltages either at normal frequency or high frequency cannot exist over any great extent of the system, as the losses would be tremendous. Since flashovers do occur on systems which must be attributed to electrical causes, it would naturally follow that these flashovers must occur due to a high voltage extremely localized or to a comparatively low voltage which might extend over a considerable part of the system.

The insulated-control system properly designed and applied is not deficient under an impact or under the most severe voltage conditions, but, what I believe is even more important, it raises the flashover voltage under conditions which might exist over a considerable portion of the system and which are capable of causing arcs to strike to ground at comparatively low voltages.

Laboratory tests in this connection may be made even more severe than those on the line, but it must be remembered that a properly designed insulated-control system shows up to advantage under these very severe conditions. The fact that line losses increase very rapidly with an increase in voltage is a fundamental assumption in the application of an insulated-control system. Without this conception, it sould practically be necessary to assume that if we prevent an arc at one place, it must of necessity occur at another. Some of the present-day systems have a short-circuit current such that the current in an arc to ground is little if any greater than the normal full-load current. On some of the large systems of the future, however, this current may be very high and it is essential that the transmission system be freed from arcs or flashovers, if at all possible. If the assumptions of the insulated-control system have been correct, the problem of preventing flashovers is not a difficult one. It is, however, essential that the insulator or system have a sufficiently high flashover to prevent an arc to ground for any disturbance existing on the system. When the design of towers and the effect of cross arms and braces is taken into account, the problem of obtaining a high flashover voltage for any conditions is comparatively simple. Even in cases where factors which control the electrostatic field in the vicinity of the insulator are not given consideration, the insulating system as discussed in the paper offers a means of raising the flashover which may have been materially lowered by the tower design.

Mr. Peek has made the statement that the grading ring is used in radio work. While this is true, it must be remembered that the ring soon reaches its voltage limitation when used in radio work. There is quite a difference between operating a radio station and a transmission line, for if a plume starts on a ring operating on a radio station, it is necessary only to lower the voltage and start over, whereas a discharge from a ring on a transmission line line usually results in a shut-down. If it were not for the voltage limitations of the ring under high frequency the results shown in Figs. 4 and 5 would not be possible. In fact, during the war considerable time was spent in developing the insulated control so as to permit higher operating voltages on the large aerials than were feasible with the ring.

The question of puncturing of the insulated control has been raised and we only have to consider operating records to see that the danger from this is negligible. If it is possible to puncture an insulated control on test, it naturally follows that this control must be functioning. It, of course, is possible that the control may be punctured owing to too low a factor of safety or due to poor design. This matter, however, is readily taken care of, as there are literally millions of insulators under more severe conditions than those imposed on the insulated control without showing evidence of being broken down electrically.

As to the insulators shown in Figs. 10 and 11, it is readily seen that although the insulator in Fig. 10 may have a very favorable gradient when the ratio of flashover voltage to stress imposed on the section is considered, it does not follow that this string will make any better showing, as the limiting factor is air break-down between conductor and line. If higher factors of safety were needed in the individual unit to prevent surface discharge or unit flashover, this is easily possible with the scheme shown in Fig. 11. It was pointed out, however, that an ordinary string of uniform 10-in. units will have a much higher flashover if properly equipped with an insulated-control system than the special string having a number of different types but without the control system.

The performance of the insulators discussed by Prof. Smith is due to the control of air break-down. If tests are made at normal frequency, the performance is exceedingly fine. If, however, the insulators are used with large metal shields which increase the field strength around the conductor, flashovers are likely to be induced under line conditions. For this reason, it would appear that the effect of the field on the conductor may be a limiting factor in the type of insulator rather than other considerations such as lack of surface resistance. De Ferranti some 40 or 50 years ago devised a similar type. It was found, however, that the wood-stick member would frequently burn under fairly mild conditions. A type of insulator somewhat similar to that shown by Prof. Smith, but with an insulated control in place of the small ring or torus was devised for radio work. The electrical performance of these insulators is rather spectacular, but it is believed that the increase in field intensity about the conductor occasioned by the metal shields will increase the difficulty of the insulating problem.

Mr. Peek and others have inferred that the insulated control would be of little or no practical benefit to the transmission line, as the frequencies used were not those of the transmission system. Owing to an error, Fig. 7 was repeated in the printed paper, whereas another figure showing the performance of bus insulators with and without insulated controls for normal as well as high frequency was left out. This sheet shows that the

insulated control as applied to a bus insulator greatly raises the flashover voltage at normal frequency and that the flashover voltage at high frequency was really due to the break-down of the air path shunting the insulator. The limiting air break-down is clearly shown in the photograph in Fig. 3 of the paper.

Insulated controls are being installed on several systems to eliminate flashovers and the records during the coming season should give much valuable information under operating conditions. In one case, the voltage will be practically doubled with clearances so much less than what are considered necessary for the higher voltage that if the operation of the system is at all satisfactory, it must necessarily prove the effectiveness of the device.

LIGHTNING AND OTHER TRANSIENTS ON[1] TRANSMISSION LINES (Peek) LIGHTNING[2] (Creighton)

Pasadena, Cal., October 14, 1924

F. W. Peek, Jr.: In some respects Mr. Creighton's conclusions are not as far from my own as might appear at first glance. The effect on transmission lines is determined wholly by the gradient. The fact that he has very high energy values is due to the high voltages or high cloud heights that he has assumed.

Mr. Creighton finds lightning oscillatory because of the very low value of resistance that he takes for the spark or bolt. In this I cannot agree with him. The specific resistance that he has taken was for a short very high-current dynamic arc. Such resistance is low because it is determined by the metallic vapor from the electrodes—in other words, a huge arclight.

The conduction of a lightning spark is determined by the ionization of the gases of the air and not by metallic vapor. The specific resistance in gas conduction is very much higher than in metallic-vapor conduction—in fact they are not of the same order. Even in sparking-over an insulator string at 60 cycles the initial break is gas conduction and it takes an appreciable time before the metallic vapors come into the arc. This initial spark can generally be seen in insulator flash-over photographs as a bright line independent of the rest of the arc. If specific resistance corresponding to gas conduction is taken it will be found that the discharge will be either non-oscillatory or very highly damped.

J. B. Whitehead: Since the time of Franklin there has been no question as to the electrical nature of lightning, but not until recently have we been able even to approach a reasonable certainty as to the particular forms of discharge and the values of electrical quantities occurring in lightning strokes. Even now our knowledge is very approximate, and the conclusions we have drawn are likely to be upset at any time. Messrs. Peek and Creighton compute the values of voltage, current and energy of a lightning discharge, from the known values of spark discharge in the air, and the assumption that a thunder-cloud and the earth constitute a parallel-plate condenser. The experimental evidence on which the conclusions are based, are the laws of spark discharge as we know them from direct tests, observations of potential gradients at the surface of the earth during lightning storms, and now, in Mr. Peek's case, experiments with laboratory models of transmission lines and cloud, and in Mr. Creighton's case, deductions from values of resistance of high-voltage electric arcs. The conclusions in each case are in approximate agreement as to the probable gradient at the surface of the earth at the time of the discharge. Mr. Creighton's estimated value of the voltage of the cloud is seven times that of Mr. Peek's, which leads to a corresponding difference in the values of current and energy. The two papers differ particularly in their estimate of the form of the discharge; Peek holding that usually the discharge consists of a single pulse, with occasional heavily damped oscillatory discharges. Creighton, on the other hand, concludes that the lowest frequency of a lightning stroke is about 50,000 cycles per second. Peek's conclusion is in conformity with that of a number of others who have worked in this field, and Creighton is making a radical departure from a considerable mass of expert opinion, when he assumes that the discharge is always oscillatory. He bases his conclusions entirely on the low value of the resistance of a high-power arc, assuming that the discharge path of the charged condenser formed by cloud and earth is such an arc. I do not think that he has made out a good case for this. There appears to be two serious objections to his view. The first is the assumption that all of the resistance of the discharge lies in the spark or arc itself. In the passage of the spark, electric charge is drawn from wide areas of both earth and cloud. As is well known, the earth may have considerable values of resistance. Our knowledge of the effective resistance to the passage of charge through the mass of a cloud is not very definite, but I believe that in this case it would be found that this resistance is considerably higher than that of the surface of the earth. For example, the heavily ionized air between two corona-forming lines unquestionably has a very high resistance. The second objection is the assumption that the specific conductivity of the lightning streak is the same as that of the vapor of a sustained high-current arc. In the latter case the electrodes between which the arc is formed are vaporized, and it is this vapor which constitutes the conducting medium of the arc. No such source of conducting ions is present in the lightning streak.

It is probable that lightning discharges take a wide variety of forms. It would appear, however, from these two papers, that the evidence that we now have is quite good as to the unidirectional pulse as the commonest type of discharge, that such oscillations as do occur are very heavily damped, and that there is little or no evidence of a prevailing type of oscillatory discharge of relatively high frequency.

H. Michener: The portion of Mr. Peek's paper which deals with the ground wire is of particular interest to me as the value of the ground wire has been discussed at great length by various members of the Edison organization. Our present 220,000-volt lines have always been equipped with the ground wire with the exception of about 60 mi. of one line. The operation of this 60-mi. section, without ground wire, has been the same as that of the 60 mi. of line parallel to this and which has a ground wire. These two 60-mi. parallel sections are located in the San Joaquin Valley.

In planning for a new line from Los Angeles to Big Creek it was necessary for us to decide for or against the ground wire. This line will be located in the mountains and the foothills nearly all of the way and 75 per cent of the footings will be in rock. We have interpreted the results of the experiments that Mr. Peek has reported in his paper to mean that a grou wire on a line in a location such as this will give only 2 per cent more protection for the line than it would have without any ground wire. On this basis we have decided to build the line without a ground wire, but to design the towers so they will carry a ground wire safely in case we should ever want to install one.

H. T. Plumb: There is not enough caution thrown out similar to that of Mr. Peek about seeing that the ground wires and lightning arresters are properly grounded. In this Western country where there is not much soil, and where that soil oftentimes is thoroughly dried out, it is difficult to get ground connections and I want to suggest something which I have been advocating and using for several years. That is, making a coupling with the earth, not through conductance, but through capacitance; connecting to something that is extensive and that is a good conductor, and let it make the connection to ground by capacitance. I believe that will very materially add to the protective value of many lightning arresters which are not now properly grounded.

1. Journal A. I. E. E., Vol. XLIII, August, p. 697.
2. Journal A. I. E. E., Vol. XLIII, December, p. 1144.

J. Slepian: The very interesting quantitative results which Mr. Creighton obtains, although admittedly somewhat speculative in nature, have a very great practical value for those engaged in combating the effects of these atmospheric disturbances upon power systems. It is very gratifying to find a general agreement as to the magnitudes of the voltages which may be induced on transmission lines, and to find that there is a logical relation between these magnitudes and the dielectric properties of air.

Mr. Creighton has not limited himself to the study of induced surges on systems, but has estimated the quantities in the lightning stroke itself, voltage, current, power, frequency, etc. These quantities depend on the capacity, inductance and resistance of the discharge path. The first two factors are geometrical in nature and may be calculated with considerable confidence. The resistance of the broken-down air making up the lightning stroke is a much less certain quantity. Mr. Creighton, by taking the results on the conductivity of heavy-current arcs in the laboratory makes it seem very plausible that resistance in the lightning path is small compared to the reactive ohms in the lightning circuit, and so neglects it in calculating current and power. The current and power so obtained are appalling. The practical conclusion to draw is that against the direct stroke to a power system we are helpless. Our puny lightning arresters are futile, discharging their hundreds or even thousands of amperes from the stroke involving millions of amperes.

We are better situated, however, with respect to the induced surges. Here the currents involved are well within the capacity of modern arresters. And since, fortunately, direct strokes are rare, while induced surges are frequent, we may feel confident that these arresters are really rendering an effective service.

By assuming that the resistance in the lightning stroke is small, Mr. Creighton arrives at another conclusion which at first sight would seem to be of very great importance for induced strokes. This is the oscillatory character of the lightning discharge. A remote stroke then, might induce on a system a surge of such low voltage that it would not discharge through the arresters, and yet which on account of its oscillatory nature, might develop a dangerous resonance in the vitals of a transformer. I wish to show that this apparent danger is actually non-existent.

I need merely to point out, that developing a resonance is a a cumulative phenomenon and therefore takes place only for wave trains which are sustained or only slightly damped. The first cycle of the train starts the resonant system oscillating; the second cycle finds itself in phase with this oscillation and increases it further; the third cycle likewise finds itself in phase and feeds still more energy into the resonant system. Thus the resonance builds up, and the energy stored in it will amount to many times the amount supplied by the first cycle. Things are otherwise if the wave train is strongly damped. The second cycle in the train, because of its smaller intensity, adds only a little to the energy supplied by the first cycle; the third cycle still less, and so on. Thus the total energy supplied to the resonant system by the damped train is little more than that supplied by the first cycle, and a cumulative resonance does not exist.

Now, I shall show that a lightning stroke is always of this strongly damped character. Where is the damping resistance? In the radiation! The column of highly conducting air, stretching up one mile high is the most effective antenna one could find for radiating the 50,000-cycle energy from Mr. Creighton's cloud. It is, in fact, as all lightning strokes must be, granting low ohmic resistance in their paths, an open oscillator oscillating at its own natural period. Such oscillations are always strongly damped by their own radiation. Textbooks on radio telegraphy show that in such natural oscillations, the second cycle is only about 30 per cent of the amplitude of the first; the third cycle will then be less than 10 per cent of the first, so that practically, we may say that the train is limited to two cycles. Hence a cumulative resonance is impossible.

It must not be thought that the radiation resistance which causes this great damping will seriously affect the calculations of Mr. Creighton. Very considerable resistance may be added to an oscillating circuit without affecting the maximum current very greatly. For example, the maximum current in a critically damped circuit is equal 1/2.718 times the maximum current in that same circuit with resistance reduced to zero.

John B. Taylor (by letter): "Does lightning oscillate?" The question is not a new one in our discussions. Sixteen years ago (see A. I. E. E. TRANSACTIONS, Vol. XXVII, pages 684, 783 and 795) Mr. Creighton was assuming oscillations in lightning flashes with frequencies of 1,000,000 cycles, and I was characterizing such a figure as unreasonable for a mile-long stroke because the velocity of propagation in space is wholly insufficient to move a charge back and forth over a mile in a millionth of a second. This objection related only to the estimated figure for frequency, irrespective of low or high resistance in the discharge circuit which determines whether the discharge oscillates or not.

Mr. Creighton, in his present paper, defends the idea that the typical cloud discharge is oscillatory and now calculates or estimates 50,000 cycles per second for the one-mile-long discharge between earth and a cloud one mile in diameter. The capacity of the cloud to earth is given as 1/100 micro-farad which, in round figures, requires an inductance of 1 millihenry to give the oscillation frequency of 50,000 cycles. This value of inductance seems much too low for a straight-away conductor a mile in length well separated from any return circuit. A value of inductance two or three times as great appears more reasonable.

However, this point does not appear so important as the omission of anything in the picture to indicate what becomes of the moving charge or current at the two ends of the mile-long flash. His argument for the presence of oscillations is that the flash itself has a definite diameter greater than ½ in. and approaching 1 ft., and that the resistance of a flash of such size is low enough to permit the discharge to persist in oscillations. But the charge and discharge must move in the cloud from the main flash to the edges. This will add perhaps a mile to the length of the discharge path, increasing the inductance, and properly further affecting the estimates of frequency. It is hard to picture a thunder cloud with moisture particles or drops in such contact as to provide an extended conducting path of low resistance. A suitable picture of the cloud itself seems quite as essential to the theory as a picture of the main flash.

Mr. Peek straddles the question by saying that *some* lightning discharges are oscillatory. He does not tell just what class of experimental evidence is taken to justify his conclusion that oscillations at times occur. For his cloud of assumed dimensions (1000 ft. square, 1000 ft. elevation, a smaller and lower cloud than Mr. Creighton's) he figures that there will be oscillations with frequency of about 140,000 cycles if the resistance of the discharge path is below 1000 ohms.

Messrs. Creighton and Peek both make reference to experimental work on the other side of the Atlantic by Mr. H. Norinder who reported in *Electrical World*, Feb. 2, 1924. Mr. Norinder made experimental observations of induction from natural lightning flashes, and, with a cathode-ray oscillograph, secured evidence that none of a number of lightning flashes studied were oscillatory. As the cathode-ray is not subject to the mass and natural period limitations of the vibrator in the more familiar oscillograph, it serves well for studying electrical oscillations at frequencies of a million or more cycles. Mr. Peek must have overlooked this fact when reading the Norinder article for he states immediately following the mention of Norinder's work:

"....it is not possible to tell from oscillographic records just how steep such waves are because of the relative slowness of the apparatus in responding."

Mr. Creighton disposes of Norinder's conclusions by making a distinction between oscillations in the cloud and in the flash, and promises to discuss this at a later date.

From these two papers and from the Norinder article, it appears that Mr. Creighton holds a brief for there being oscillations in a lightning discharge, basing his case on assumptions as to dimensions and physical characteristics.

Mr. Peek says there may or may not be oscillations but invites the question: "What is the evidence?"

Mr. Norinder gives experimental evidence that oscillations are absent in lightning flashes.

E. R. Stauffacher: Mr. Michener has told you that we were somewhat reluctant to give up the idea of using an overhead grounded wire on the new Big Creek line, but it was finally decided that the possibility of the ground wire breaking and coming in contact with the conductors outweighed the protection which the ground wire would afford. I should like to ask Mr. Peek one question regarding the value of overhead grounded wire as applied to the location of this wire with reference to the conductors and the structure of the tower.

The Big Creek transmission towers are constructed approximately as shown in Fig. 1 herewith with overhead grounded wire fastened at point A. Can we assume that the values given by

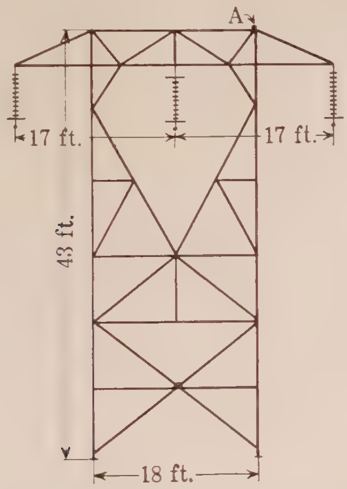


Fig. 1—Standard Big Creek Tower Showing Location of Overhead Grounded Wire With Relation To Conductors

Mr. Peek for the protective value of overhead grounded wire apply to transmission lines having the conductors in horizontal configuration, separated a distance of from 17 ft. to 22 ft. to the same extent as if the conductors were placed in vertical configuration for example, and spaced closely together? If this distance between conductors were 11 ft. instead of 22 ft., can we assume that these values given, that is, the protective values of the ground wire, will be the same in both cases?

It has been the practice of the Southern California Edison Company during the past year to use an extensive system of grounding at the major substations, and we are now beginning that practise at our minor substations. We feel that one ground wire to a ground well did not give us sufficient protection and we are now adopting the policy of connecting everything together, thus approaching a condition of the station building and equipment sitting on a copper mat.

As regards lightning arresters, the ground leads are brought to pipes driven immediately along the row of arresters. From these pipes connections are made at several points to the network of underground conductors. Mr. Plumb's remarks regarding the use of some metal object, such as the framework of a building, or a fence around a substation, leads me to ask Mr. Peek this question: Suppose the grounded wire on an overhead transmission line is connected to steel towers that are set in rock, which is an insulator, do we or do we not have a good ground for the dissipation of external discharges and thereby gain advantage of the protective value of an overhead grounded wire?

W. A. Hillebrand: Referring to Mr. Peek's paper, and the discussion of lightning phenomena, and also to Mr. Norinder's referred to therein, if you have a bound charge, after the lightning discharge breaks, that bound charge, presumably, will proceed to travel in opposite directions. If, for instance, the discharge should be six miles long the frequency would be in the order of 30,000 cycles per second. Now, this charge is passed from a highly charged region, that is, where the dielectric is charged, into a region where the dielectric is not charged, so correspondingly it will be absorbed in the dielectric and the energy will be dissipated. As shown by Dr. Whitehead, these damping losses are absorbed in the dielectric region, as the charge passes, and it is reasonable to assume that energy will be returned and oscillate at this frequency through the circuit.

What bearing has the ground wire on this? To a man with radio experience a ground wire is very similar to a counterpoise used in high-power radio transmitting stations for the purpose of reducing the ground resistance, increasing the current, the energy of oscillation, and the voltage is developed directly proportional thereto. Now, if there is anything in the possibility of developing an oscillation, as a result of a traveling wave, then anything that tends to reduce the rate of damping will increase the vigor of that oscillation and the voltage developed in direct proportion thereto.

One of the most complete ground wire systems that I have ever seen had three ground wires on top of a steel tower and three conductors directly below it. This vertical distance between was roughly six feet; the voltage of the circuit is 33,000 volts; the length of the system is about 100 miles, there were about 18 miles of steel towers carrying this combination. Now, as a result of their troubles, due to lightning, on that 33,000 kv. circuit, they would not consider an insulator with less than a normal 66-kv. rating that measures, roughly, 13 x 12 inches, having a 60-cycle flash over of about 200,000 volts. Now, is it possible that you have two compensating effects that counteract one another? The undoubted shielding effect of the ground wire system, also this other effect reducing the ground resistance, increase the oscillation that may result from a closely coupled counterpoise, and of the vigor of that coupling, the closeness of it, there is ample evidence from a number of sources.

Now, it is possible that the nature of the ground itself has something to do with the intensity of lightning disturbances and of their frequency. According to the fundamental electrostatic law the tube of force terminates in the cloud at one end and the charge in the ground at the other. This charge within the earth is drawn up as an amperage current in the earth. There is presumably only a certain amount of energy for the accumulation of the charge. If the ground resistance is high, is it possible that that in itself is a limiting factor? The ground resistance is low in a well watered valley, or on the surface of a subterranean water system and there you will get characteristic thunderstorms of greater violence than elsewhere.

If general corona is allowed to develop the energy is probably immediately or quickly dissipated. On the other hand, both experience and theory tell us that if that energy is allowed to break loose at a single point, at a clamp, or some other point, you will get a streamer that may run to a great length. It is disputed whether or not this thing does exist. There are many evidences that point unquestionably to the fact that we have something of that kind.

The experiment that Mr. Peek shows so beautifully of artificial lightning splitting blocks of wood, has been performed by natural lightning for many years. Over a year ago, in Northern California, I saw a pine tree, four or five feet in diameter, an old

tree the center of which was partially rotted out, struck by lightning and it broke off about half way up the trunk and the flash continued down, cork-screwing down the tree. I don't know how many kilowatt-hours, but probably not more than half a dozen, would be required to shatter that tree. The interesting thing which Mr. Peek did in his experiment, was to dissipate the energy where he wanted to. If he wanted to burn up No. 6 iron wire weather-proofed, he subjected the antenna lead to a stroke of lightning and the wire evaporated leaving the weather-proof covering intact. When he wanted to split a stick of wood, his conductor was large enough and the energy was dissipated in the wood. That was what happened in that tree; this current of an unknown number of amperes split the tree to pieces, came down to the bark and where it entered the ground there was no sign of any disturbance whatsoever. I looked around the roots of the tree to see if there was any evidence, but apparently the conductivity at that portion of the circuit was too high.

R. P. Jackson (by letter): In the exceedingly interesting discussion of the possible limits of ligtning discharges from cloud to ground, it does not appear that any consideration was given to the fact that the upper plate of the conductor, that is the cloud, is not a metal plate of comparatively low resistance, but is a great group of small segregated, conducting particles. The assumption that the earth resistance is negligibly low is probably quite correct. The resistance of the main path of the arc might readily be within the range indicated. In the cloud itself, however, the arc or current path must branch into a multitude of filaments ultimately reaching each individual droplet. What the resistance of this umbrella or mushroom-shaped portion of the spark path is, is difficult to surmise. It is probable that even if the discharge would otherwise be oscillatory, there is a powerful damping action due to the inability of successive alternations to spread out to the whole cloud and a rapidly increasing resistance is thereby interposed. The effect therefore may be quite different from that of an ordinary discharge through a reasonably fixed resistance and although the initial wave front may be steep it would appear as though the damping action of the cloud resistance would be very great.

F. W. Peek, Jr: Mr. Michener and Mr. Stauffacher have both asked regarding the ground wire. As I understand it, in considering a new line, the question came up as to whether a ground wire should be used or not. It was decided that a ground wire should not be used, not because the ground wire when properly and favorably installed, would not give good protection, but because, under the conditions of this line it could not be well grounded, and, therefore, would not materially effect the lightning induced on the line. I think that was a correct conclusion because if the ground wire cannot be well grounded it gives very little protection. The factor of protection, to a great extent, depends upon the resistance.

In the tests that I made, the ground wire was, in most cases, approximately at a distance from the conductor equal to the spacing between adjacent conductors. My data is applicable to Mr. Stauffacher's line. There is one interesting point that I would like to make clear. When the conductors are arranged in a horizontal plane the voltage induced on each conductor will be about the same so there will be practically no lightning voltage between them. The lightning voltage will be between conductors and ground. When the conductors are in a vertical plane, there will be considerable voltage between conductors, as well as between conductors and ground.

One interesting fact about the ground wire is that one ground wire will protect any number of other conductors. If one conductor is protected and other conductors are placed, they will receive protection without reducing the protection on the first conductor.

Answering Mr. Hillebrand, a number of years ago in Colorado we made experiments on a 25-mi. idle line. In these tests the voltage between line and ground was measured by gaps while the nature of the discharge was determined by means of a rapidly revolving photographic film. The gaps indicated that the first discharge was a steep wave front followed by the oscillation of the line at its natural period, which, in this case, was about 1800 cycles, or at very low frequency. With the longer lines, the frequency would, of course, be much lower than this. The effect is thus that of a steep-wave-front impulse which may be dangerous, followed by a more or less harmless low-frequency oscillation.

The ground wire tends to increase the damping, just as a short-circuited turn in a transformer would. The actual resistance of the ground itself is very low, because of the great cross-section. It is, in fact, much lower than the resistance of the ground wire. The ground resistance is high where it is part of the ground-wire circuit. This follows because of the small contact area where the ground connection is made.

E. E. F. Creighton: In formulating a closure on the several interesting points brought out in the discussions of my paper it seems pertinent to state my attitude of mind. As a developer of electrical protective devices I am endeavoring to learn the severest conditions to which the protective devices will be subjected. If there are oscillations a certain type of protection should be provided. If finally it should be proved by measurements that lightning is never oscillatory it will simplify the design of electrical protective apparatus. Meanwhile continuity of electrical service is too important to permit us to assume no oscillations when possibly they exist. The cathode-ray oscillograph, properly applied, will tell the tale and put an end to our speculations.

My speculative paper is founded primarily on some new experimental evidence of low resistance of sparks. By the term sparks is meant the accepted designation of conduction by gasses and is to be distinguished from conduction by metallic vapors. I think the metallic vapor was driven from the conducting stream in which currents as high as 30,000 amperes were recorded by the oscillograph. Mr. Peek differs with me in my assumption that the lightning streak has the same low value of specific resistance as I measured in these tests. I cannot be absolutely positive that metallic vapor was not present in the three-foot length of arc. Unfortunately these tests could not be included in my brief paper. Metallic vapor travels about 2000 ft. per second. The driving forces in the arc and spark were great enough, I think, to give greater velocities to the metallic vapor which should have driven it bodily out of the conducting stream.

Be that as it may, the latest researches by physicists, Dr. Millikan for example, have shown that the outer layer of electrons on such atoms as nitrogen and oxygen may be torn loose under extremely heavy current densities. These free electrons in great numbers might supply high conductivity in the spark stream. Getting electrons free from gases, like nitrogen and oxygen, requires more agitation of the atoms and bombardment than from metallic vapors. Under low-current densities nitrogen and oxygen in a spark have admittedly lower conductivities than metallic vapors. It seems to me, however, there is great risk of being wrong to assume that under the intense forces of a lightning discharge the ionization of nitrogen and oxygen is not appreciably greater than when measured at lower current densities. The electrons exist in great numbers in the gas atoms. It is a matter of experience that the electrons under bombardment can be separated from the atoms and thereby become conductors of electricity. The degree of conductivity is the question debated.

In Dr. Whitehead's discussion I wish to correct a misunderstanding. He says, "Creighton is making a radical departure from a considerable mass of expert opinion when he assumes that the discharge is always oscillatory." I do not assume the discharge is always oscillatory. I agreed with these experts

(second page of my paper) that they are right. I think many lightning discharges are non-oscillatory and the cloud part (the blue brush and weak spark portion) of every discharge must necessarily be non-oscillatory. The resistance of the path, or in other words wide-spread dissipation of the energy, is too great to permit oscillations,—according to the accepted mathematical theory. I discussed this matter of location of resistance at the time De Blois published his paper. In brief, the situation may be stated as follows: If we mentally replace the highly conducting streak, say a mile high, by a metallic conductor the top of the conductor will act as one plate of a condenser and the earth as the other. The electromagnetic energy will be stored up around the conductor. Since the oscillating current (assuming it exists will be greatest near the earth, the electromagnetic energy will be greatest there. According to this understanding the lightning bolt should fade away, beginning at the top and rapidly extending downward. The main streak of the lightning stroke is indeed a vertical antenna and it radiates a part of its energy as has been pointed out by Dr. Slepian.

Radiation of "wireless waves" by the lightning is admittedly a factor too important to neglect. Aside from the heavy drain on the energy in the lightning bolt by electromagnetic waves there is also the further drain of energy in the form of heat and light, both at relatively high frequencies. To offset these losses and thereby to keep up the possible oscillations there are sources of supply of energy which may be drawn on after the first cycle of natural oscillation. One source of energy is in the thundercloud itself. We know definitely by measurement that the energy in some thunderclouds is not given up immediately and thereby exhausted during the first stroke. Correspondingly, therefore, we may infer that the energy is not all given up by the cloud to the bolt during the first part of the stroke. This speculation is appropos to a continuation of the oscillation.

Furthermore, there is another source of energy which may be designated as "burning the atmosphere." It requires a great expenditure of energy to disrupt the atmosphere during the initial formation of the lightning bolt. Why should this energy not be returned in part, on recombination of the elemental parts,—just as for example in the combining of carbon and oxygen.

The million cycles per second as a natural frequency of lightning, that Mr. Taylor mentions in his discussion, was derived from some measurements made in Colorado about eighteen years ago in conjunction with Clay and Peek. The frequency was obtained not from lightning, but from resultant oscillation in the power transmission circuit. It is admitted that these oscillations may have been local in the circuit and not due to the lightning bolt.

In closing, I wish to point out again the characteristic attitude herein that we should look to the worst effects of lightning, with the understanding that protection successful against the worst will make all the lesser effects negligible.

ELECTRIC POWER APPLICATION IN PACIFIC NORTHWEST FIR MILLS[1]

(WRIGHT)

PASADENA, CAL., OCTOBER 16, 1924

G. B. Rosenblatt: I have recently interested myself in the electrification of the lumber industry, and looking at it as an outsider who is coming in, I have seen some things, possibly, that those who have grown up with the industry don't recognize.

First, there doesn't seem to be any formula for determining the size of equipment to put in. It is done on the basis, evidently, of general past experience and if the conditions change that experience is not changed accordingly. I want to ask Mr. Wright whether there has ever been developed any formula for determining the size of motors used in conveying machinery around the sawmill? That is, the proper size of motor for use for the chains and the rollers and the conveyors that move the products at different stages of its completion around the mill from machine to machine. In all the mills I have seen in the last couple of years, and I have seen 100 or more, about the same size of motor is used in the same application no matter whether hauling a big fir log, a little strip of pine, or a big redwood. I am wondering if somebody has determined how to figure the right size of motor for the operation of the conveying machinery around the mill.

In the metallurgical industry, with which I have had much experience, we had a definite method of determining what size motor to put on a given conveyor; we knew what it had to transfer, how far it had to raise it and all of the detailed information to enable us to figure out what size of motor was best suited for that purpose. The lumber mill doesn't seem to have anything of that sort unless Mr. Wright happens to know of, or has developed such a method himself.

Another thing that struck me in connection with this sawmill electrification, is that while everybody admits that the power factor is bad, and that it ought to be better, all they do is to attempt to cure it after it is made. It struck me that that is an uneconomic way of approaching this problem. I want to ask Mr. Wright whether any studies have been made, that he knows of, for improving this power factor before hand, rather than spending time and money in trying to cure it after it has been created? It struck me that synchronous motors could be used more generally in a sawmill. Have any studies been made to determine the feasibility of putting in these synchronous motors to improve the power factor? This matter of making a poor power factor and then trying to cure it later, I think, is an uneconomic way of approaching the problem.

Another point that occurred to me is that while we are electrifying sawmills in a large way, we are still sticking to the old steam-operated equipment at the head of the mill. Where we don't want to use steam we sometimes put in compressed air and operate the old steam machinery, but we haven't truly electrified it. On a few installations the dogs on the saw carriage are direct motor driven. That is the "Percy Dog" developed by the Chief Engineer of the Union Lumber Company. I wonder if any real work is being done towards further electrifying that part of the mill?

The same is true of the saw carriage. Nearly every saw carriage in a mill of any capacity is either steam-driven, or, in a few cases, driven by compressed air in the old steam engine. I know that one of the principal lumber companies, the Weyerhaeuser Company, at Everett, is experimenting with a completely electrically driven saw carriage, without any reference to the old steam practice, using equipment that is comparable with that used on high-speed traction elevators. I wonder if Mr. Wright can tell us whether anything else of that sort is being done?

In regard to control of certain of the sawing machinery that is moved up and down—in all the mills I have seen, those saws seem to be moved by air cylinders which are the outgrowth of the old steam cylinders. I have heard of people trying to get away from that practice and if Mr. Wright could give us any information along that line I think it would be very valuable.

C. J. Russell: The question of low power factor due to industrial loads is one which is increasing in importance year by year in the East. The subject is one which must be dealt with sooner or later, due to the great increase in industrial applications. The story is told in the East that the subject of power factor is of no interest on the Coast or in any case where power is transmitted for a long distance. It is possible, however, that when a connected industrial load reaches 400,000 or 500,000 h. p., power factor may become quite a question.

The present speaker has served for several years upon committees dealing with this subject. The late Dr. Steinmetz was a member of this committee, intensely interested in this

1. JOURNAL A. I. E. E., Vol. XLIII, December, p. 1117.

subject and in one of his last letters commented upon the fact that so little real interest had been taken in the matter.

Briefly the situation in Philadelphia, with respect to power factor may be of interest. During the war, Philadelphia was one of the greatest munition-manufacturing centers in the United States. The question of the supply of power became a serious one. Several plants had connected loads of from 20,000 to 40,000 h. p., made up of great numbers of individual motors of the induction type. Drastic rules were adopted as to power-factor requirements, a minimum of 95 per cent being stipulated. Without any trouble, however, power factors of 97 per cent were obtained through the use of synchronous motors on air compressors, pumps, etc.

From the studies made of these installations, and the effect upon production and losses of all kinds, we became firmly convinced that it was economically right to establish high power factor standards for all power installations. These were set at 80 per cent for installations on the order of 50 h. p. and 90 to 95 per cent for larger installations. Such regulations seemed severe but they have accomplished great good for the customer as well as the utility. About 25,000 kv-a. of corrective apparatus of various types have been installed on our system and the results are eminently satisfactory.

The correction of power factor is an engineering question and each case must be passed upon according to its characteristics. We have a very large capacity in synchronous motors on our lines, a large number of synchronous condensers, and many static condensers, both group and individual, have been installed within the last three years. The most important part of the results of this work is to be found in the experience of the power users who have been greatly benefitted. The results of an investigation of this subject will be published shortly in the technical press and will undoubtedly interest electrical engineers and particularly those connected with public utilities. It is rather unfortunate that power-factor correction cannot be accomplished without giving a bonus for the results or penalizing the customer who does not make the correction. The real gain to the customer himself along the lines of unit cost of his product is such that high power factor should be maintained without regard to the bonus or penalty system.

There has been much talk about low power factors being due to improper motor applications. This is a subject that is worth consideration from the Institute standpoint. It should be remembered that industrial-plant conditions are not permanent, being affected by business cycles, seasonal cycles and perhaps labor changes. Any change in raw materials may make a radical change in the amount of power required. For all these reasons we can hardly expect that absolutely correct sizes of motors can be installed to fit the demands each hour, day, season or year.

Another point that must be considered in dealing with the motor size question, is due to the cyclic character of many mechanical operations. We have been making a careful investigation of this matter in Philadelphia. We find many cases in which, while integrated readings over 15-minute or one-half hour periods would indicate that motors installed to operate machines are entirely too large, they are of the correct size to meet the cyclic demands which may be of such short duration or occur so frequently that it is impossible to use flywheel effect.

The last word in this matter is that the motor must be of such a size as to do the job for which it is installed. It is put there to produce goods and if too small to meet the peak demands, production cannot be obtained to the full capacity of the machine. It is, of course, well known that a loss in production of from 1 to 5 per cent, and tests have shown as great as 16 per cent, will have a serious effect upon the plant costs in most forms of industry. The correction of power factor has been thoroughly covered from the technical point of view, but is worthy of careful study by members of this Institute on account of the economic benefits which will result from high power factors.

In conclusion it may be of interest to repeat what Dr. Steinmetz said about a month before he came West. He stated that he had come to the decision that there was no single great economic factor in our business remaining undealt with as important as power factor. He called attention to the enormous amount of money spent to attain a very small percentage of additional efficiency in the generation of electricity, and to the fact that the economics of power factor are of importance in the isolated plant as well as the public utility in case alternating current is used, and affect all the operations from the generator to the device utilizing electric power.

C. A. Heinze: It is a fact, as brought out in Mr. Wright's paper, that without any general knowledge of how much power is required in the lumber-mill industry, it occurs, and occurs quite frequently, that motors too large for the requirement are installed and naturally, when working under average conditions, operate at very low power factors. In most of the large industrial plants that I have in mind in Southern California the average power factor of the plant will not exceed 65 per cent. This is very important and should be given careful consideration. Partial correction lies first, in providing proper-sized motors; second, in providing a motor to drive a group of machines having intermittent operations; and, third, providing on some heavily loaded continuously operating machine an over-excited synchronous motor for correction of the plant power factor.

J. L. Wright: In general I wish to state that the electrification of sawmills has been accomplished by sort of a rule of thumb method. This was not the fault of the electrical people exactly but at first we were not able to get the sawmill men to cooperate with us. These mills were all at first designed by sawmill machinery people who had not only steam engines to sell; but they had transmission machinery such as shafting, pulleys, etc., as well and it was almost impossible to get them to see the electrical way.

There are a lot of things we should like to do and can do but the lumbermen will not give us a chance to do any experimenting.

In regard to conveyers, it is almost impossible to figure out or obtain any kind of a formula to figure out the exact h. p. required for driving conveyors in a sawmill. Nearly every sawmill is designed differently; in other words, there are no two mills alike. As a result, if you go ahead and try to figure out any correct size of a motor to drive a conveyor, you will find, after it is operating for a while, that conditions change altogether, and that this conveyor may be called upon to carry a much larger quantity of refuse than was originally intended.

Conveyors taking trash away from a sawmill are called upon to do different work nearly every day. The amount of trash that a conveyor carries away depends entirely upon the kind of logs brought into the mill to be cut up into lumber. When a log comes into the mill they have no idea what percentage of the log will be waste. In some cases, nearly the whole log is waste. As a result the trash conveyors are called upon to carry an abnormal amount of trash away from the mill. But again a log may come into the mill that would have very little trash, when the conveyor will have little to do, so it can readily be seen that it would be impossible to calculate a motor that would be correct for all conditions. As a result we generally put on a motor that is large enough to take care of the maximum conditions.

In reference to the question as to the use of synchronous motors for driving an edger, we have given this a great amount of thought, but cannot find how this is a logical application of a synchronous motor. In considering the problem, we have tried to find out what results might be expected to be obtained from a synchronous motor, the comparative costs, and also the space required by the synchronous motor.

The load of the edger motor is very intermittent and varying. The peak values during a cut is on an average of 200 to 250 per

cent of full-load current. If we use a synchronous motor for this drive,—the time that we really want power-factor correction, on the peak load of the edger, we shall get very little correction, while at the light load of the edger, when power factor correction is of no benefit, correction will be possible. I therefore, do not see how much benefit will be derived from putting a synchronous motor on an edger.

Some of the disadvantages are due to the location of the motor with respect to the edger. It is very important that as simple a construction of a motor as possible be installed. The space is very limited for the motor and also the place is very dirty. Therefore, if we do use a synchronous motor it will be necessary to have it completely enclosed and to obtain excitation current from an external source.

As stated in the paper, the logical application of synchronous equipment for power-factor correction in a sawmill is driving such a load as an exhaust fan or air compressor with a synchronous motor. These drives have a constant load at all times and the synchronous motor can be set so that a certain amount of power factor correction is maintained during the entire day. This will help the entire system and will be of benefit when you really need it.

Another way of correcting power factor in the sawmill is by means of a synchronous condenser. We have a great number of mills in the northwest with power factor corrective apparatus, as mentioned above, and they are obtaining the results desired.

ELECTRICITY IN MINES[1] (Stone)

Pasadena, Cal., October 16, 1924

G. B. Rosenblatt: The paper apparently deals mostly with the application of certain electrical equipment to coal mining and makes little reference to metal-mining practise with which I am much more familiar. If it will be remembered that the remarks I have to offer are based on my experience in the metal-mining field and may fit in with coal-mining practise only insofar as they may apply to it, I would like to offer the following comments:

Emphasis is laid by Mr. Stone on the importance of maintaining ventilation underground. He then suggests for the drive of the fans to maintain this ventilation, a synchronous motor of the type designated as "super-synchronous," that is, the type whose stator revolves during starting. Admission is made that this type has never been applied to such work but the author advocates it. It is my opinion that the design of the so-called super-synchronous motor has not progressed to the point where it may be considered sufficiently reliable for such an important application. This type of motor has today been used almost entirely for the drive of ball or tube mills in cement plants. While continuity of operation is important in such service, it is not paramount. If a tube mill shuts down due to motor trouble, a certain production is lost—but if a mine fan is shut down due to motor trouble at critical moments, men die. In connection with investigations conducted by a prominent western mining organization which decided on synchronous motor drive for its tube mills, existing installations of the so-called super-synchronous motor were investigated. The results of this investigation were that the synchronous motor with stator revolving for starting was not deemed altogether reliable. It may therefore be considered that this type of motor in its present stage of development is not suitable for mine-fan drive where human lives are at stake.

In discussing the applications of synchronous motors to mining work, it is to be regretted that no mention has been made of the really large field for such installations afforded by air compressor and pump drive. The introduction of synchronous motors into the mining industry is really a very important matter to all of the large power systems which supply such load as well as to the mining companies which generate their own power. All metal mines use a large amount of compressed air. Simple direct-connected synchronous motors are most readily applied to the drive of the requisite compressors. Of late, synchronous motors have also been very successfully applied to driving mine pumps and there are now some very large underground pump stations in western mines equipped entirely with synchronous-motor-driven pumps.

The author seems to feel that the field of usefulness for storage-battery locomotives underground is decidedly limited and possibly decreasing. My own experience does not bear this out. In metal mining particularly, we find the properly designed storage battery locomotive increasing in popularity and use. It is the poorly designed and improperly applied storage-battery locomotive that has caused the failure of certain installations of storage-battery haulage. Coming right down to fundamentals, the comparison is not fairly to be made between the trolley type or gathering-reel locomotive and a storage-battery locomotive, but should rather be made between the two types of haulage systems as a whole, including in such comparisons all items that go into the actual cost of hauling a unit of ore or coal over a unit of distance. The machinery designer—the factory engineer—may be much interested in different advantageous details of one type of locomotive as against another, but the purchaser and the user—the man that pays the bills—is primarily concerned with what it costs to haul his ore or coal per ton and per mile.

Mr. Stone states "induction motors have been installed on electric shovels but from all information the writer has been able to secure, the d-c. Ward-Leoanrd control is much more dependable and the operating costs considerably lower."

The relative advantages of a-c. versus d-c. for large shovel drive has been a moot question among interested engineers for the past several years and each system has had its staunch supporters. Some while ago, a prominent copper company which had for years been doing their mining with over 20 large steam shovels decided to electrify the shovel operations. The arguments submitted by the various supporters of the two systems of electric drive—a-c. versus d-c.—were carefully and painstakingly reviewed by the management of the mining company who finally came to the conclusion that all the arguments presented were based largely on opinions and deductions and not on known facts, so they set out to find of the facts for themselves. They bought and installed two shovels—both identical mechanically—one equipped with Ward-Leonard d-c. equipment, the other with a-c. induction motors. The electrical installation of each type was supervised by the manufacturers advocating that particular type, so that both shovels had the advantage of the best electrical engineering talent. These shovels were then put into regular mining operation and their performance carefully watched and recorded by both the engineering and operating staffs of the mining company. After several months operations, the mining company decided that sufficient data had been collected to permit it to determine upon the type of shovel for its subsequent electrification. In order to assure itself that its judgment in making this important decision would be as correct as possible, the mining company secured the services of one of the best known American electrical engineers and a prominent member of this Institute to assist its own engineering department in selecting the most advantageous equipment. As a result they bought shovels equipped with a-c. induction motors—not the Ward-Leonard d-c. equipment.

The test records of this mining company covering the actual operation of both types of shovels under real mining conditions are most interesting. They indicate that the a-c. equipment: (1) Costs less to buy than the d-c.; (2) Is much simpler than the d-c.; (3) Should have materially less maintenance than the d-c.; (4) Consumes slightly—very slightly—more power than the d-c. per average ton of ore dug; (5) Can dig a bit faster than the d-c. equipment; (6) Imposes somewhat greater peaks and considerably poorer power factor on the power supply line.

These tests were made with big railway-type shovels mounted

1. Journal A. I. E. E., Vol. XLIII, December, p. 1147.

on caterpillars and the results, while conclusive, may not apply to all installations. However, the outcome of these large scale service tests certainly confutes Mr. Stone's statements regarding the general superiority of d-c. equipment for electric shovels.

C. H. Matthews (by letter): This paper seems to cover the application of electrical equipment to coal mines from the manuacturer's standpoint and I wish to make several comments that affect the practical use of the equipment described.

Mine ventilation, as Mr. Stone states, is of paramount importance and the most reliable and proven apparatus must be selected. The common design of synchronous motor with magnetic clutch is a very reliable piece of equipment and is suitable for driving fans of almost any capacity and speed.

Induction motors have proven efficient and reliable for driving mine fans but must be used with some form of speed reducer whereas the synchronous motor can be efficiently built for almost any speed for direct connection.

Where power-factor correction is necessary synchronous motor-generators and synchronous motors driving air compressors usually give the desired results, and the use of synchronous motors on mine fans and centrifugal pumps is desirable for lowering the power costs.

The use of storage-battery locomotives is a necessity in many metal mines if economical transportation is to be obtained and since the requirement of "permissible" equipment in gaseous mines the storage-battery locomotive seems to be getting a more permanent berth. There are many engineers who differ on the advisability of storage-battery applications, but there still remains a demand which must be satisfied.

The suggested speed of 3 to 3½ mi. per hour for gathering locomotives was probably based upon storage-battery locomotive speeds which speeds are maintained at a fairly constant rate over the working day. With trolley locomotives the speed depends upon the trolley voltage so that in the majority of mines a trolley locomotive designed for a speed of 3 to 3½ mi. per hour at rated voltage and draw-bar pull may not handle the same output as a storage-battery locomotive of the same weight and geared for the same speed. Since the voltage has a direct bearing upon the speed of trolley locomotives and as the trolley voltage is seldom maintained at normal value it would seem desirable to design for speeds of 4 to 5 mi. per hour at rated voltage and draw-bar pull. Some of the locomotive manufacturers used 500-volt motors on 250-volt power to obtain slow speeds for gathering. This was an easy way to secure data on slow-speed service but it reduced the rating of the motor equipment which from an operating point of view is not desirable. A study of motor curves on slow speeds of 3 to 3½ mi. per hour when using 500-volt motors on 250-volt power shows that the light-load speeds do not increase in the same manner as with motors designed for 250-volt slow-speed operation, so that a drop in trolley voltage causes a decrease in speed over the whole speed curve which is not compensated for to any great extent by light loads.

Graham Bright (by letter): I believe that a little more attention should be given to the question of the isolated power plant for coal mines. It is true that with central-station power available, in the large majority of cases there is little excuse for the existence of the isolated power plant. There are, however, some localities where central-station power is still not available, and there are other cases where the central-station rates and form of contract are such that where the mining company has a fair supply of good water, and in some cases can utilize waste fuel of no commercial value, it would not only be feasible but would be economical to install an isolated plant.

The most important question, by far, in regard to the installation of an isolated power plant, is that of water supply. In most cases, the water available in the vicinity of a coal mine is very poor, and cannot be used in boilers without a treating plant. It is true that it is possible to treat water so that it will be very satisfactory for boiler service, but these treating plants require a certain amount of skill for their operation, and this skill is seldom available in the coal fields. In a great many cases, as soon as a man is educated to take care of the treating plant, he is likely to leave the locality, and the only one available for this particular situation is, figuratively, a man who knows nothing whatever of this kind of work, and no one has the time to teach him the details. The result is that the boiler plant gets in very bad shape and may be ruined in a short time.

Mr. Stone mentions the desirability of having a stand-by source of power where the mines are gaseous or collect water rapidly. A form of gasoline-engine-driven generator has been frequently applied, and Mr. Stone mentions that the hoist and fan, under such conditions, can be operated at reduced speeds. With the ordinary type of unit, operating at full frequency, this this can, of course, be accomplished with a fan only in case it is of the two-speed type, or of the variable-speed type. The hoist can be operated at reduced speed only by means of inserting resistance in the hoist motor, and this does not greatly reduce the amount of power required, since the extra power is absorbed by resistance. Where it is necessary to keep the fan and hoist in operation, the writer has proposed a scheme of supplying a gasoline-engine-driven generator, operating at reduced frequency. This permits the fan to operate at a lower speed, with very much less power, and permits the hoist to operate at reduced speed with an economical use of power. A plant of this type has been installed at one of the mines of the Y. & O. Coal Company, near Pittsburgh, and low-frequency emergency power can be made available within thirty seconds after loss of the central-station power.

Mr. Stone indicates that the load factor of the anthracite mine will be something like 42 per cent. I believe that in some of the mines where very heavy pumping takes place the load factor is even higher than 42 per cent. In the average bituminous mine, however, where the ventilation and pumping are both light, the load factor will average about 25 per cent, and in some cases may be as low as 15 per cent. This, of course, is one of the reasons why the cost of power at some of the smaller bituminous mines is rather high on a kilowatt-hour basis.

Mr. Stone illustrates a very ingenious scheme for allowing the use of a synchronous motor for operating a mine fan. The objection to the synchronous motor has always been that it has a very comparatively low pull-in, while for fan operation the motor should have a pull-in of 100 per cent. Unless a great deal of power-factor correction is required, the installation of a motor of sufficient capacity to produce the proper pull-in would not be economical. The use of a clutch has not been advocated much in the past, due to the added complication. I believe the time is coming when the synchronous motor will be used very commonly for the installation of mine fans, but I feel that the motor described by Mr. Stone is only a step in the ultimate direction. The objection to this type of motor is that extra collector rings are required, and in many cases these collector rings will carry a voltage of 2200. Another inherent objection to this type of motor is that for economical design, the peripheral speed of the rotating element of the motor should be fairly high. The stationary part of a motor is generally made of steel punchings, which furnish the required active iron surrounded by a shell of cast iron or cast steel. In case the stationary part is to rotate, as described by Mr. Stone, then the limit in speed would be determined by the outside diameter of the stationary part. Even when made of cast steel, this part would have to be carefully balanced and additional bearings supplied. This would mean that the peripheral speed of the rotor would be very much less than the economical speed, and for this reason, the motor would be more expensive than the standard type. As stated before, I believe that the motor described by Mr. Stone is but a step in the evolution of the synchronous motor, and the time is coming when we will have what is practically a standard motor with a magnetic or similar clutch, preferably inside of the motor, which

can be operated automatically, and this motor will not cost a great deal more than the standard motor.

Mr. Stone's curves, showing the power taken by different types of motors, are very interesting, and indicate that the brush-shifting motor is well worth considering, where variable speeds can be utilized.

I am glad to know the stand that Mr. Stone has taken regarding the application of storage-battery locomotives to mines, as I know of a great many cases where misapplications have been made and the storage-battery locomotive has been given a "black eye" simply because of misapplication.

The application of contactor control for mine locomotives has a great many advantages. In the first place, it makes a much safer controller for the operator. A number of accidents have occurred where the operator has been seriously burned, due to the ordinary drum type of controller blowing out. With the contactor control, the operator has only the master controller close to him, and the danger of his being burned is very remote. Another advantage of the contactor control is that it forces the mine management to install sufficient copper to give a fair voltage regulation. This not only saves a considerable loss in power, but increases the output of the mine, and cuts down the maintenance of apparatus caused by burn-outs.

The application of contactor control also lends itself to dynamic braking, without seriously complicating the control itself. It also simplifies tandem operation in that only one power cable is required between locomotives.

The application of equalizer systems is becoming quite prevalent for both two- and three-motor locomotives, as a proper equalizing system will not only increase the power of the locomotive by keeping the load equally distributed on the wheels, but will make a much better tracking locomotive, thus preventing costly and annoying derailments. The usual method of applying an equalizer system to a two-axle locomotive is a rather difficult matter if a stable locomotive is desired. Unless the equalizer bars are restrained in some manner, the locomotive may become tilted to one end or the other and remain in that position. This is also true of the three-axle locomotive, where the axles are equalized all the way along each side. Where this type of equalizer is used, you will frequently notice that the locomotive is considerably closer to the track at one end than it is at the other. One way to eliminate this unstable condition is to equalize two axles on the sides and cross-equalize the third axle.

A feature illustrated in Fig. 9 of Mr. Stone's paper, but not mentioned by him, is the method of taking the end thrust on the end of the axle, rather than on the wheel hub. This is a distinct improvement on the older method, and is being almost universally adopted. It provides an easy method for taking up the end play and for lubricating the surfaces which take the end thrust. It also keeps the supply of lubricant for the main journals in a much cleaner condition, and for this reason the maintenance on the main journals and brasses should be much reduced.

I agree with Mr. Stone that the question of whether to use the synchronous converter or the motor-generator set for substations is large determined by the nature of the power supplied. With good voltage and frequency regulation there is no reason why the rotary converter should not give as good service as the motor-generator set, and it will have much better efficiency. In many of the bituminous mines, the sub-station will operate a considerable portion of the time at very light load. The losses with a synchronous converter are only about one-half of what they would be with a motor-generator set under these conditions. Where sufficient copper is installed, the constant voltage supplied by the synchronous converter will give very satisfactory operation. The over-compounding obtained by a motor-generator set in many cases indicates a considerable loss, and the high voltage near the sub-station during heavy loads is often injurious to compound and shunt-wound motors working in the vicinity. The automatic sub-station has come to stay, and with this equipment available there is no real excuse why good regulation should not be obtained in most of the working places in the average coal mine.

Mr. Stone's remarks in connection with the application of specially shaped drums to hoists are very much to the point, and where short, fast cycles are required, a very careful analysis must be made or the effect of the specially shaped drum will be entirely defeated.

In connection with electric shovels, the question of which is the best type of equipment to use has not as yet been finally settled. There seems to be a great deal of merit in the application of direct-current motors, using motor-generator sets and Ward-Leonard control. This type of equipment is rather complicated when it comes to the number of machines involved, but, of course, has an extremely simple and efficient control. The straight alternating-current motor, however, requires very much less equipment, and where the power system has sufficient capacity, this type of equipment has some advantages over the direct-current equipment. Just recently a large mining company in the West, which uses a great many shovels for a stripping operation, has conducted tests on both types of equipment, and have come to the conclusion that alternating-current is more efficient and less costly to install. From the results of the tests and investigations, they have decided to start equipping all of their steam shovels with the alternating-current system, using induction motors.

The direct-current shovel equipment in operation at this time using motor-generator sets and field control seems to be rather sluggish when compared to the alternating-current, and it is generally found upon comparison that the alternating-current equipment will dig and load more material in a given time than the direct-current of the same capacity.

F. L. Stone: Referring to Mr. Matthews' very interesting discussion, I agree with him entirely in his comments on storage-battery locomotives. There are places where their installation indicates good judgment on the part of the management. Like many other pieces of apparatus, it could almost be considered as a necessary evil under certain conditions. I tried to make this clear in the paper. It is the promiscuous and careless application of storage-battery locomotives to work that they are not suited to perform that the writer objects to.

Reference has been made to a prominent mining company in the West, where two practically duplicate shovels were installed, one being driven by a-c. motors and the other by d-c. motors, with variable voltage control. Before the tests on these equipments had reached a stage from which anything very definite could be deduced, the mining company purchased seven additional a-c. equipments. After the shovels had been in operation a year or more and some of the new a-c. shovels had been delivered and were put in operation, the mining company then felt that it had sufficient data to make an intelligent selection. It then purchased eight d-c. equipments. This, I think, together with the fact that many other companies have, on investigation, purchased d-c. drive, fully substantiates my statement.

In regard to Mr. Bright's discussion, will say that I am sorry I did not have time or space to go into great detail in connection with the problem of isolated plants versus purchased power.

Mr. Bright's comments on the super-synchronous motor show a very clear understanding of the subject. I might state that over fifty of these machines have been shipped and put in service. The collector-ring trouble which Mr. Bright refers to was taken care of by thoughtful and careful design. No trouble from this source has been brought to the writer's attention. The stator, as Mr. Bright points out, must be and is, very carefully balanced. The peripheral speeds of the stator are not at all excessive, and the factors of safety are very large. The ease of control while starting the load by means of the band brake is a very noticeable feature in this motor. The load can be brought up at a high rate of speed or at a low rate of speed, or the rates can be varied during the starting cycle at the will of the operator.

ELECTRICITY'S CONTRIBUTION TO THE STEEL INDUSTRY[1]

(Pauly)

Pasadena, Cal., October 16, 1924

G. E. Stoltz: One important contribution that electricity has made to the steel industry is due to the economy and ease with which energy can be transmitted throughout the plant and the economy with which this energy can be utilized in electric motors. Steam engines were employed to drive machinery in our steel plants before the advent of the electric motor. Steam was usually generated in several boiler plants as one large boiler plant was not feasible due to the leakage in the long steam lines and the drop in steam pressure. The steel plants in fact had to be laid out with the idea of locating their mills in such a way that a group of them could be near some individual boiler plant. The reciprocating engine does not lend itself to high steam pressures and low vacuum which is possible with the use of steam turbines for generation of electric power. For this reason the generation of the steam was not as economical as is possible where steam turbines are used.

The large difference between steam drive and electric drive is in the transmission of energy from the generating station to the load. It is not unusual to find a steam plant where during business depression only half of the steam is utilized for useful work. The remainder is lost in condensation, steam traps and leaks. It is difficult to locate all of these leaks and they may go on for years without notice. Where energy is transmitted electrically any leakage between phases or ground is immediately brought to our attention and in order to continue successful operation the cause of the trouble must be immediately removed.

The next greatest difference between steam drive and electric drive is at the point where the energy is utilized. Steam engines may have fair economy at some selected load but the reciprocating parts are bound to wear and destroy the economy of protection. As the engine grows older it is more difficult to maintain good economy. This is not true with the electric motor as its efficiency is not effected with years of service.

While it is physically possible to use engines and also to transmit steam from the boiler plant to these engines, electric motors and the necessary transmission lines require very much less space and electric wires can be carried to almost any secluded spot so that the steel plant which uses electric drive can place its generating plant at a location most convenient for generation of power. This is usually near the blast furnaces where blast furnace gas is utilized. The mills then can be located without any reference whatsoever to convenience in transmitting power to the motors. It is this flexibility and economy of transmission of power, as well as the economical utilization of energy at the load which forms one of the greatest contributions electricity has made to the steel industry.

Ralph Bennett: I have been thinking a good deal, in recent years, of this matter of by-product power and Mr. Pauly's paper brings up a very interesting proposition. If you accept the theory of monoply for public utilities, is the concern having the monoply warranted in making a rate, we will say, of 1 cent at one end of the line and four cents at the other in order to maintain an average rate of 3 cents, making the low rate to an industry which is wasting, up its stacks, as heat, more than sufficient power to operate its motors and on which they could install a steam plant at a cost which would show a good earning. This is to me a fascinating angle, in the matter of rates, and the theory of monoply. Is a utility expected, and should a utility be allowed to take the load offered if the load can be more economically supplied by the individual?

1. Journal A. I. E. E., Vol. XLIII, September, p. 831.

THE DEVELOPMENT OF A SUSPENSION-TYPE INSULATOR[1] (Smith)

Worcester, Mass., June 5, 1924

and

Pasadena, Cal., October 15, 1924

Discussion at Worcester

E. M. Hewlett: In trying various materials in experimenting on the first suspension-type insulator we found that any compound or any material that *can* carbonize, *will* carbonize. I am in hope that by distributing the strain in the way that Professor Smith has done, the carbonization will be reduced and the life of the rod lengthened, but it seems that in this electrical work, anything that *can* happen *will* happen. For instance, when an insulator is subjected to fog, you get a little dampness on the surface. Or when you get it out in the Middle West, in the Salt Lake section, where you get alkali dust, then you get a surface condition that will start a little static and start a little leakage. These conditions, with the available materials, are likely to result in deterioration.

The thing that we have always been looking for on all insulators, and I think in a good many other things, too, has been a suitable material.

Now, of course, if we can get a better porcelain, a porcelain twice as strong, or 50 per cent stronger, a little tougher, with a better dielectric strength, we can do quite a good deal, even with our present design. If we had a ceramic material, which we felt was safe under tension conditions and wouldn't crack and drop the line, why, then we could work something of this kind of a design. On the wireless antennae, they use a 50-in. long tube, 3½ in. in diameter, and they shield the ends with a ring very much in the same way as Professor Smith has done here. They do not use the rings for rain shields, but just as distribution rings.

On transmission voltages above 110,000 volts, it has been found that the lower disk on suspension-unit strings takes a larger percentage of the total electrical stress than the other units of the string. Therefore, on the higher voltages it has been found necessary to put grading rings on the strings in order to balance up the stresses. That process can be carried on so that the present types of suspension units can be used for any voltages that we know of at the present time.

We are in need of materials that will withstand arcing static and corona. The discovery of such materials will not only render possible numerous suggested designs, but will also open the field to many new designs of insulators for high-voltage transmission insulation.

C. L. Scott: In 1904—twenty years ago this summer—the International Electrical Congress was held in St. Louis. It had many sections. One of them was "Power Transmission." I happened to be its Chairman. One of the best groups of transmission people that had ever come together were there, presenting and discussing papers—something like half of them related to the line or the insulator.

It is interesting to read now the criticisms of the pin-type insulator, its construction, its theory, its size and its performance. V. G. Converse, who was the man who had made the underhung insulator that Mr. Skinner spoke of, had a long paper on insulators, a historical paper which described and illustrated all the different sizes and types. He refers to his underhung insulator or underscrewed insulator and goes on after saying that the pin insulator had been growing in size until it approximated a Chinese pagoda, to give another form of the same thing with an improved construction.

Dr. Perrine suggested the building of a little cottage over each insulator to protect it from the weather, a sort of a cubical, 4 or 5 ft. in size, open on two sides to let the line run through. Everybody was pointing out the insulator as the limitating element in transmission which had then reached 66,000 volts. We had the transformers but not the insulators.

1. Journal A. I. E. E., Vol. XLIII, August, p. 689.

M. H. Gerry, the man who started the first 50,000-volt plant for the Missouri River Power Company—spoke of his insulator experience, and made some very significant remarks. He described and illustrated some experiments showing the discharge over glass plates—simple static experiments—and he said, "The direction in which we will have to look in the future is a study of the electro-static conditions. They are coming into consequence at these higher voltages."

Three years later, in 1907, papers at the Niagara convention of this Institute by Buck and Hewlett presented a new type of transmission. The problem had been to hold the line in place, to hold it steady. It had been above the cross arm. They proposed putting it below. They proposed long spans hanging the wire from a succession of suspension insulators. They changed the law of the insulator from the third power to the first power. When you double the size of a pin insulator, you increase its weight as the cube; when you double the underhung type, you use two insulators increasing the weight by two instead of eight. There were two very significant things; one was the presentation of a new system, and the other was its reception. The insulator caused a new era in transmission, but the hearers didn't recognize it; the discussion was trivial.

The curve of increasing transmission voltages for the last 30 years or more runs up fairly uniformly to 1903 and then keeps on a pretty straight line at about 66,000 volts for five years. Then there is a sudden jump up to 110,000 all at once. Then it went on up. Why? The suspension insulator had come; it changed the whole trend of transmission.

Now we have again something new. When Buck and Hewlett discarded the upright insulator, because it was mechanically wrong, they got it mechanically right by shifting the position 180 degrees. What has Prof. Smith done? He has treated the problem in a broad, engineering way. Most people have tried to hang on another insulator or change the shape of the petticoats or change the metal clamp or improve the porcelain.

Professor Smith does not modify; he starts *de novo*. He proposes a dozen or more different requirements to be met and they seemed wonderfully exacting and almost impossible. But he had the courage to lay them out and then to meet them.

Now, what has it come down to? Why nothing at all but a metal umbrella with a wooden handle with an ornament at the bottom, but it apparently meets the mechanical and electrostatic requirements.

I wonder whether we are going to be as slow as the American Institute of Electrical Engineers was nearly twenty years ago in recognizing that maybe some new thing with big possibilities has come such as was presented by Buck and Hewlett.

V. Karapetoff: I should like to ask Professor Smith a question or two in regard to his design, if I may. Electrostatic systems may be divided into *glow* systems and *sparkover* systems. Take two large spheres, a short distance apart and raise the voltage to a point where there is ionization on the adjacent surfaces. The flying electrons will also ionize by collision the remainder of the space between the spheres. Therefore, there is no intermediate stage of corona formation and a breakdown takes place almost at the same voltage as the first corona appears. On the other hand, take two small spheres, placed quite far apart. As the voltage is raised, a potential gradient is reached at which ionization by collision begins at the surfaces of the spheres, where the voltage gradient is at a maximum. As the air is broken down, the diameter of the spheres is seemingly increased because the ionized portion may be considered as part of the metallic conductor. Therefore, a condition is reached at which a stable equilibrium is possible, because the voltage gradient beyond the ionized range is not sufficient to cause further ionization by collision. I call such a system a glow system. As the voltage is raised higher, the ionized layer increases in thickness and then streamers begin to form. Finally a complete breakdown takes place. This is, then, the difference between a spark-over system and a glow system.

If I understand correctly, the apparatus to be protected should rather have glow characteristics, while the protective apparatus should preeminently have spark-over characteristics. If I want a quick gap to protect some apparatus, naturally I would select a condition in which there is no intermediate corona stage; while if I want something protected then, I should judge, a glow arrangement is preferable. When the voltage rises beyond a certain limit, the apparatus becomes partly self-protecting by the formation of ionized corona regions, and when the voltage goes down, the apparatus field becomes normal again.

I understood Professor Smith to say that in his insulator a sparkover takes place without previous corona formation, and I should like to ask him if this is theoretically possible, with the shape of the guard ring that he has, or with the lower terminal and the umbrella above. His photographs show that the electrostatic flux spreads out from the lower ring reaching a maximum dielectric flux density there. So that, theroetically, at least, a stage is reached at which the voltage gradient at the ring exceeds that necessary for ionization by collision and an ionized layer is formed. The same applies to the edge of the umbrella. I do not say that with the construction used these layers are necessarily harmful; I only should like to know if they exist.

Another question which I should like to ask Professor Smith is this: He spoke of a hollow field. To me, a hollow field means a field which is more intense on the outside than on the inside. For example, if we have an iron pipe, longitudinally magnetized by a coil, we might say that it has a hollow field, in the sense that the flux density in the material of the pipe is greater than in the interior space. Now, the permittivity of wood is at least twice, if not more than twice, that of the air, so that with the same applied potential and the same average voltage gradient we should expect a higher flux density in the central wooden stick than in the surrounding air. Can such a field be called hollow? The field is very skillfully arranged and the lines of force are almost parallel to the outer surface of the wood, so that there is no corona formation on the surface. I understand this point. But is it not true, nevertheless, that the dielectric flux density is higher in the rod than it is in the air?

This may seem like splitting hairs, but seeing that we are now in the midst of a new and rational epoch in the development of insulators, let us start our terminology right, before it is too late.

H. A. Stanley: All the experiments we have seen, and the talk we have heard, have had to do with the insulator in the vertical position. I assume that we are not going to get away from the use of insulators in the strain position. This particular insulator is not adapted for use horizontally. For instance, the lower bowl, I should judge, would hold water in the horizontal position, and I would like to inquire if the thought is to work out something different for use in the horizontal position?

The second point is the copper. I suppose that when the manufacturers get around to selling this device to us they will try to make it in some cheaper material. I would like to inquire if there is any reason, theoretically, why it couldn't be made of galvanized iron.

Mr. Bowlen: The point Mr. Stanley just brought out about the insulator being placed in a horizontal position, is, I think, of considerable interest, and I believe, in that connection, there is a strain insulator on the market at the present time which uses a wooden core as its principal tension member, covered with porcelain tubes filled with petrolatum or oil. That is used on a span something like 3000 ft. long and it is in successful operation, it has a means of re-filling the space between the wooden core and the porcelain. That might be the answer to putting it in the horizontal position.

Discussion at Pasadena

W. A. Hillebrand: Professor Smith, perhaps, has revived the first form of suspension insulator that was brought out. We have insulators today that operate and constitute a not unreasonable charge upon the system. If you take into account

obsolescence their charge is less than that of many other elements of the system. Today, it is probably less than the direct depreciation charge of wood poles and cross arms, and taking into account obsolescence, it is less than the charge upon the earlier and comparatively recent types of prime movers, generators and oil switches. It is a charge which the industry is able to bear without imposing an undue burden. I think it is the best practical insulator we have today because it works. The only question is that of making it a commercial success. It has got to be something better or cheaper, to offer equivalent service at a lower cost than that which we have today. The only question then is that of application. Unquestionably it will be tried out and in sufficient quantity to give a demonstration. The operation of this insulator depends upon the satisfactory maintenance under field conditions of an initially established gradient.

This matter of bird droppings causing flashovers, to my mind, is a question as to whether with two units your field will be strong enough to exclude foreign particles and moisture. There is a leakage problem that is, perhaps, the most serious of all. We have a new material, which is treated wood.

Now, there is one thing that is fundamental, and which applies to both the manufacturer and to the user of that type of insulator, that is, the failure of a single piece of dielectric. and that applies to any known dielectric, means the dropping of the line. That is, a failure from any cause whatever, straight mechanical failure, puncturing, burning due to leakage, arcing due to flashover—anything that causes a line interruption means a loss. Now, experience has shown that you can have as many as 30 per cent of the pieces of dielectric fail mechanically, or electrically before obtaining the first line interruption. That is solely a matter of the number of pieces used; that determines the reliability. With insulators of the types now in common use, the reliability is the function of power of the number of insulators in the string. That is one of the most commonly overlooked and one of the most fundamental applications in regard to insulators today. On the other hand, the probabilities of interruption with an insulator of this kind is in direct proportion to the number of pieces of dielectric in use. That is, that every additional piece of dielectric you add constitutes an additional hazard instead of an additional protection. It puts on the manufacturer an almost unbelievable requirement with regard to reliability. You may be able to obtain it, but on the basis of experience I would say it should be approached with the greatest of caution.

J. B. Whitehead: Professor Smith has adopted in his insulator two devices which we have known for sometime, namely, the arcing ring and impregnated wood as an insulating material. The particular aspect of his work to which I want to call attention is the study that he has made of the properties of the arcing ring, or screen, and the method that he has adopted in that study. We have had arcing rings that will take the arc and save the insulator for sometime, but Professor Smith has made a study of the shape of these rings in a systematic and scientific way and has arrived at a form of ring which gives a uniform potential gradient over the insulating member. He thus eliminates regions of high potential gradient and has, therefore, reduced to a minimum the probability of an initial brush, or corona, or spark-over. It is a scientific investigation and it should, therefore, be emphasized as an example which we should all attempt to follow in putting experiments of this kind under way.

I suppose that the methods are being followed in the study of the impregnation of the insulating member. Of course, the open question in connection with the insulator, is the life of the single insulating member. It would appear to me that it is going to be a question of the power of the surface of this member to withstand the action of the elements. We know that porcelain, originally apparently perfectly safe, eventually, under the action of the elements, temperature and so on, developed a cracked surface which eventually leads to failure. In the case of the impregnated wood member we would seem to have the possibility of avoiding in a large measure, that particular type of failure. If we can obtain an impregnated material, which is more or less plastic, and which, therefore, will yield to the expansions that are brought about by temperature change, it would appear that we might have a surface which would accommodate itself to existing conditions from day to day. It appears to me, however, that if we do not obtain such a type of impregnated material, there is a considerable element of danger in such an insulating element. For, if this impregnated wood disintegrates we will get a fibrous substance in the path of the potential gradient and this will lead to brush discharges.

C. E. Skinner: As I understand it, Professor Smith's investigation is not based primarily on the use of wood in a strain insulator; but on a study of the potential gradient and a design such as to permit the use of a strain member so placed that when an arc is formed it will not be along the surface of the insulation. This arrangement permits the use of wood, which in the past has proved most satisfactory in many other applications as an insulating material. It has the advantage of great mechanical strength and is readily obtainable. It has the disadvantage of being carbonizable and difficulty has been experienced from time to time in providing suitable impregnation.

Methods of impregnation have been studied and results have been obtained which seem to warrant the assumption that methods are now available which will justify the use of wood in this connection, provided it is not subject to arc over, and Professor Smith's tests show that this need not be feared in this particular design.

Professor Smith's insulator is especially interesting as being the first radical departure from the type which has been generally accepted as standard for many years. Line insulation has for some time been considered the limiting factor in the use of high-voltage transmission. This insulator gives promise of removing this limitation.

I do not understand that Professor Smith is ready to advocate this insulator for commercial work until more field experience is obtained, and tests are under way which will give this field experience. The wood strain is merely incidental to this type of construction, and any other material which will satisfy the mechanical and insulation demands could be used to replace it.

H. F. Elliott (by letter): Electrostatic shields, or terminals, of the type proposed by Professor Smith, have been used with rod, tubular and other forms of insulators for radio antennae and associated services since 1914 or perhaps even earlier.

The high losses which accompany corona at radio frequencies, and the extremely destructive character of corona at the higher frequencies, forced the adoption of special types of insulators with suitable shields to control the electrostatic fields at this comparatively early date. The accompanying photographs, taken during 1916, 1917 and 1918, may be of some historical interest in this connection.

Fig. 1 shows the type of porcelain-rod insulator and disk shields which were used for several high-power radio antennae during 1916 and 1917. Fig. 2 shows a specially shielded string of standard suspension units which was used with the same antennae. All of these insulators functioned satisfactorily and without visible corona at potentials of the order of 100,000 volts, r. m. s., and frequencies ranging from 15,000 to 50,000 cycles.

Shielded strings of standard suspension units in a variety of combinations were tested at the Stanford University high-voltage laboratory during 1917. The results of these tests will be found in the paper by Mr. Frank G. Baum entitled "Voltage Regulation and Insulation for Large-Power Long-Distance Transmission Systems," PROCEEDINGS A. I. E. E., Vol. XL, 1921, pages 1067 and 1068.

Fig. 3 is a sketch of a porcelain-rod antenna insulator designed during 1917 and tested at the Stanford University high-voltage

Fig. 1

Fig. 2

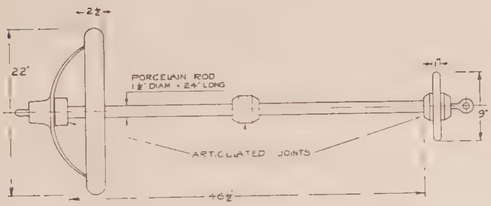


Fig. 3

Fig. 4

laboratory during the same year. Using 60 cycles, and with the insulator dry, the first pin points of corona appeared at 140,000 volts; intermittent streamers occurred at 225,000 volts and large streamers but no flashover occurred at 350,000 volts, which was the limit of the testing equipment. With the insulator

Fig. 5

thoroughly wetted, there was some brushing at 100,000 volts, but the changing currents quickly dried the surface.

During 1918 porcelain-tube insulators of the type shown in Fig. 4 were developed. These have since come into general use and have proven highly satisfactory, both as to electrical

Fig. 6

efficiency and mechanical reliability. Fig. 5, shows such a unit under test at 183,000 volts, r. m. s., and 46,000 cycles. The shape of the surrounding electrostatic field is clearly shown by the position of the corona streamers, which are entirely clear of the insulator proper.

Fig. 6 shows a special high-strength antenna insulator designed during 1918 for service involving potentials of 135,000 volts, r. m. s., to earth, frequencies of 12,000 to 30,000 cycles and a working load of 20,000 lb. *in tension*. Each of the four porcelain

tubes comprising this unit was approximately 6 in. diameter by 6 ft. long and each tube had an ultimate tensile strength over 20,000 lb. Recently, similar units have been constructed whose ultimate tensile strength exceeds 35,000 lb.

Fig. 7 shows a pedestal-type insulator, with electrostatic shield, under test at 234,000 volts, r. m. s. to earth and 51,000 cycles. This unit was one of a number used for special radio-frequency switches which were operated, without the slightest indication of corona, at a potential of 135,000 volts. The shape of the electrostatic field as controlled by the shield is indicated in the photograph by the corona streamers.

The possibility of constructing the electrostatic shields of antenna insulators so as to shed rain was considered at an early date but was not immediately adopted because the insulators had to operate in a nearly horizontal position, as shown in

Fig. 7

Fig. 1. More recently, however, the practise of using cone-type electrostatic shields which also act as rain shields, has been adopted with great satisfaction for radio antennae employing insulators in a vertical position. An account of the development and testing of units of this type is given in a paper by Mr. W. W. Brown in the PROCEEDINGS of the Institute of Radio Engineers, October, 1923.

It will be noted that all of the insulators described in the foregoing are of porcelain. Many other materials have been tried, some with apparently excellent success in the laboratory, but none, except porcelain, has proven satisfactory in service for potentials above a few thousand volts.

H. B. Smith: In response to some of the questions that have been asked, I will make a few suggestions.

First, with respect to the suggestion regarding fog and dust which has been made—and I will combine with that the question Professor Karapetoff raised with respect to the hollow field.

Professor Karapetoff is correct in stating that there is greater density of the dielectric flux within the stick than immediately outside, but comparing the space along the length of stick, as compared with the short spacing between metal terminals, we have outside of the surface of the stick a density variation exactly conforming with his description for a hollow field and the stronger field on the outside tends to deflect particles of moisture, dust, etc., in the direction of that field and away from the stick.

Reference was made to the size of the insulator. It does look large, here in this room, but it doesn't look large out on a transmission tower for such a voltage as would be employed where such an insulator would be used. The parts are not heavy.

A question was raised as to the material. These, you understand, are the first insulators of this size, and for convenience, the hood is made of spun copper. That was just for the small number. It was not feasible to prepare dies for pressing, as would be done in quantity. As soon as that is done, the material cheapest for production, considering depreciation, will be used. There is nothing in the metal that is used that affects the operation of the insulator, theoretically.

If I may take just a moment in reminiscing, referring to what Professor Scott has said, I would say that when his paper of 1898 was presented—depending upon wires of small diameter—it was felt that a limit for voltage might be reached of 55,000 or 60,000 volts. It stimulated us here in Worcester in 1900 to 1902 as soon as we had developed the transformer, (which is now in the room below and was used in the demonstrations this morning), to apply higher voltages to a transmission circuit that was placed along Boynton Street, and we used wires of larger diameter.

In a thesis presented by Cook, Davis and Wiard in 1901, the results are shown of the effect of increasing diameter and prove clearly that 60,000 volts was not prohibitive.

In those days, before Professor Ryan went to California, we were in close contact with each other—we were working together more less on this question—and this fact was communicated to Professor Ryan and we had quite a little correspondence on the matter.

Soon after that, Mershon made other tests in Colorado and the results of those tests were sent to Professor Ryan. Mershon's results did not agree with our results in Worcester, so that both Professor Ryan and myself were somewhat skeptical as to the accuracy of either Mershon's work or the work that we had done here in Worcester.

Professor Ryan later sent to Worcester results of his experiments on the effect of pressure, and also going back to some old work on the same subject, made seventy-five years before—the work of Paschen, so that taking into account the difference in elevation of Colorado and Worcester, he found that our results agreed, substantially.

We then had confidence and Professor Ryan went on with his classical paper that he presented to the Institute in 1904, which gave us the foundation for the law of corona losses between conductors.

Reference was made to the large diameter of the hat of this insulator. You must remember that the hat is connected to earth. You can make one continuous hood for three or four insulators, if you choose, instead of splitting it up.

The question of deterioration of organic materials, under such conditions as these, is, of course, the important question, and it is a question that can only be answered finally by experience on the insulators in service. We have tried to put the insulating member under the most favorable conditions possible to prolong its life. We have attempted to remove visible corona. Whether ionization coincides with visible corona, may be a question. Visible corona does not appear until very close to the point of break-down, and we operate the insulator at half, or less than half that voltage.

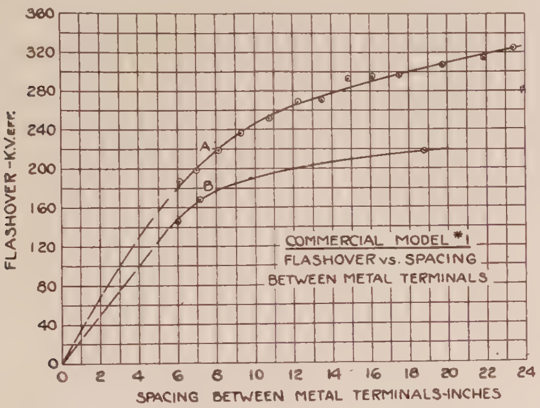
With regard to the question of the horizontal strain insulator, there is no attempt to meet that condition with this present insulator. The same principles can be employed in such a type of insulator. I think there is a little misunderstanding as to the construction of this torus. It has a perfectly continuous surface.

The comment of the operating people who will have to deal with these insulators in service, is perfectly fair—that it should be tried out. That is the thing that we propose to do. We will then know just the limitations and just what may be necessary to do to apply these same principles, which I believe to be right, to the actual conditions as imposed in service. We hope that we

can meet them the first time they go into actual service but that isn't always done.

H. B. Smith: Possibly some of you may have thought that the insulator I am suggesting is radical because of its apparent departure from existing practise, but I cannot regard it in that way. It happens that in 1898 I succeeded in producing a transformer for 175,000 volts in a single unit. I think that at that time it was the highest voltage single unit transformer. Transformers had previously been used with high-tension circuits in series, that is, a number of units in series but not in cascade as we are doing now. In 1901 we built our single unit 500,000-volt transformer. As a result of having these transformers many people from all over the country were sending us insulators for testing. Therefore, the present insulator is the development of a quarter of a century and it is not a recent thing in my mind, except in its final form at the present time. It has been a gradual development of thought and experience through a great many years.

The pin type of insulator reached its limit and we all recognized the importance of the work that was done in producing the multiple-unit string in carrying us past a stumbling block at that time, and, in the present form of insulator the importance of the unit is recognized. The difference is mainly in producing a unit



for a higher voltage per unit and an insulator which gives a uniform distribution of potential along its insulating surface, and terminal connections for that surface such that corona is eliminated until very nearly the flashover voltage. It is that early development of corona, preceding the final voltage limit,—a result of an excessive gradient, which overthrows the whole dielectric field and fixes a lower flashover limit.

The question of puncture, as we have had to deal with it in the porcelain insulator in the past, where at the head you have a relatively thin layer of dielectric stressed to the maximum, is eliminated in the present design; we have wholly different relationships.

If we plot flashover voltage against spacing between the metal surfaces we have a curve for dry flashover as shown in *A* of the accompanying illustration. With 18½ in. spacing between metal surfaces on the unit, we have about 300,000 volts flashover value. Now, you can reduce that to 8 or 9 in., and you then have the more pronounced characteristics of the sphere gap, higher kilovolts per inch for flashover, and only a very small reduction in the total flashover voltage; with a very much lower spacing. With that smaller spacing, you will have capacity variation.

In reference to Mr. Wood's point of a standard unit, or of a variety of units, it may be a question for the operating engineer to answer whether he cares to use two standard units, with flashover of 300,000 volts each, or two together in series, as we saw yesterday, with a flashover of 520,000 volts, or whether he will use a shorter stick for one or both of those units and a more uniform distribution.

The wet flashover values run along in a flat curve as shown in *B* so that with the greatest spacing the ratio between wet and dry—for instance on the unit we saw yesterday,—is in the neighborhood of 82 per cent. As you go to lower spacing you have a higher ratio between the wet and dry flashovers. In fact, in many laboratory tests we have had unity ratio, when we had the right kind of water. With ordinary tap water and rain it will run up to 90 per cent or 92 per cent.

Now, I have not had as many rocks thrown at this, as many rifle shots at it, as I hoped might be experienced. Some of you saw the demonstration of a single unit in Worcester many of you saw the demonstration of two units in series yesterday afternoon (at Pasadena). Perhaps, I ought to say, as it was difficult to announce the matter there, that on the two units that were hung up in the laboratory, were applied 520,000 volts before flashover and I presume you noticed that up nearly to the point of flashover you could not see (in a dark room) the location of the insulators. That showed that we really have succeeded in the elimination of corona to way above working voltage. That is one of the features that makes it possible to consider the introduction of such a material as impregnated wood. We should not consider that the experience of the past, under *other* conditions, is necessarily applicable in *this* case. We all know that the use of wood insulation has been disasterous in most cases, especially, where exposed to the weather. Nor are we limited to the use of wood in this case.

The insulating member, or stick, is placed in what I have called a hollow electric field. That is, the shape of the metal hat and the torus below it is such that we have entirely surrounded the wood stick by a field of higher potential and maximum gradient than that which the insulating surface sustains. We also have an insulating surface parallel to the lines of force along that surface which gives us a uniform distribution of potential along the surface. Now, the presence of the field of higher gradient outside of the insulating surface accomplishes two or three things. It, to a certain extent, deflects particules, moisture, dirt, even heavy particles, as pieces of straw, etc., so that they do not come in contact with the stick. I don't mean to say that it will wholly *prevent* moisture, or a heavy fog, settling on the stick, but it will minimize this effect and the stick will withstand the discontinuous moisture. You may have certain conditions in manufacturing, particularly in chemical manufacturing areas, or where exposed to fogs,—especially where, coming with other deposits, where it may be necessary to clean the surface periodically, as is the case with other insulators but this insulator provides as good a surface for cleaning as I can imagine, if that proves to be necessary. Only experience in varied service will tell us what the needs will be in that respect.

You understand, I am sure, that this insulator has just passed through what I consider its developmental stage. We have now had, for some months, a group of these insulators, of which I will show you slides, on a tower in the Pittsburgh area where they are at line voltage and subjected to the Pittsburgh atmosphere near a large foundry where foundry gases are blown across them. Since I left Worcester I have received word that after several months in that service they have just passed through a period of 60 hours of continuous rain, fog and wind and there have been no failures as yet.

Now, as to the life of the sticks, we feel confident as to the thoroughness of the impregnation of the wood. The question of the weathering of the surface of the stick can only be told by service. Last winter we, for a number of months, had sticks soaking in tempid water throughout the day, freezing at night, and subjected to flashover tests twice a day. Now, I don't know how long a life period that would correspond to. Those are the facts of the case; you can form your own guess as to what length of time in normal service that would mean.

The plan that I hope to follow with this insulator is not to recommend its application on power lines at the present time with the view to superseding present methods of insulation.

That would be very unwise. Following these preliminary service and life tests, I hope to place them in limited numbers, upon a number of service lines, under a variety of climatic and other conditions, so that the experience in such service will tell whether it is a better, a cheaper, or more desirable insulator for general power line application than those now in service. That will *then* be a question that anybody can answer for himself. Of course, I would not do this except that the evidence at the present time has impressed me of the very excellent probabilities before the insulator.

ELECTRICAL APPLICATION TO IRRIGATION PUMPING[1]

(Cates)

Pasadena, Cal., October 16, 1924

L. J. Moore: The matter of testing pumping plants for the agricultural consumer has proven a very beneficial service to the farmer, because it has enabled him to know whether or not his pumping plant is delivering its proper amount of water at the proper cost for energy, and it also has forced the pump manufacturer to furnish a product which really comes up to specifications.

On August 31, 1924, the San Joaquin Light & Power Corporation had 6495 agricultural pumping consumers. These consumers represent a total connected load of 75,898 h. p., which gives an average connected load of 12.1 h. p., per consumer. It will be noted that the average size of installation is not large, and that the service is rendered to the small consumer so that each one individually takes care of his own irrigation. It is estimated that more than 370,000 acres of land are irrigated by this method on the system of the San Joaquin Light & Power Corporation. The following table gives the monthly distribution of kilowatt hours sold in 1923 on the San Joaquin System for irrigation pumping:

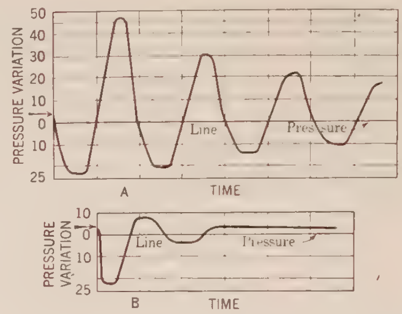
1923	Kw-hr. Sold	Total Earnings	Monthly Distribution of Kw-hr. Sales
Jan.	1,190,554	$10,928.08	1.27 per cent
Feb.	1,907,504	19,316.99	2.03
Mar.	3,937,123	34,680.97	4.20
Apr.	8,669,827	96,258.81	9.25
May	7,727,267	180,655.61	8.25
June	13,245,806	230,335.54	14.13
July	14,353,861	240,625.97	15.32
Aug.	15,332,497	235,286.92	16.39
Sep.	12,983,531	206,661.98	13.82
Oct.	6,992,437	147,754.40	7.45
Nov.	4,342,081	125,943.73	4.62
Dec.	3,065,344	110,744.37	3.27
Totals	93,747,814	1,639,193.37	100.00 per cent

From this table it will be noted that the average rate paid by the agricultural consumers is 1.749 c. per kilowatt-hour. On the better installations it has been found that the energy consumption is as low as 1.8 kw-hr. per acre foot per foot of lift for the most recent and most efficient deep-well installations. This represents a cost of approximately 3.15 c. per acre foot, per foot of lift. However, the average cost of pumping on the San Joaquin system is more nearly 4 c. per acre foot, per foot of lift.

It is also to be noted that the monthly distribution of the irrigation demand is radically different from the monthly distribution of the usual urban load. In other words, the highest demands for irrigation pumping come in June, July, August and September, while the lowest occur in the winter months. In urban loads, naturally the highest use occurs in the winter and the lowest in the summer. Therefore, it is evident that the combination of the two gives a very good annual load factor.

The use of electricity for agricultural pumping is very dependent upon rainfall conditions, and the figures shown for the year 1923 should not be taken as absolutely applicable to all years. Rainfall in the middle of the agricultural season might cause a very marked drop in the demand and a considerably different monthly distribution. Also a dry season calls for a much greater use of pumping than otherwise. As an example, the year 1924 has been very short of precipitation in California. The use of power for agricultural pumping on the San Joaquin system in 1924 for the months of January to August inclusive has been 105,300,894 kw-hr., as against 66,364,421 kw-hr. for the same months in 1923. This represents an increase for the period of 59 per cent in 1924 over 1923. Naturally there is an increase each year over the preceding year due to the natural growth of the business, but this should not, under normal circumstances on the San Joaquin system, be more than 15 per cent. Therefore, the additional 44 per cent has been largely due to the extreme dry season.

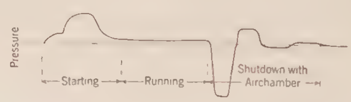
Ralph Bennett: The effect upon the apparatus of the change from the old-style engine-driven pump to the high-speed



Shut-Down Pressure Curves from a Steel Pumping Line With and Without a Friction Air Chamber

A. No Air Chamber

B. With Frictional Air Chamber



Pressure in Pumping Line with Motor-Driven Centrifugal Pump

motor-driven pump has been interesting. In many cases the system consists of a well pump and a booster that will lift against a head of 120 lb. or more and through a line several thousand feet long. Under the old condition the line pressure rose from static to operating pressure over a long period of time causing practically no shock on the line. When the old engine was shut down a correspondingly slow reduction to static pressure occurred. But with the introduction of the ordinary squirrel-type motor, with a two-step compensator, each step is reflected in a relatively enormous increase in pressure on the line which finally slides down to running pressure. I know of cases where this excess is as much as 30 per cent. As most of these lines are designed on a close factor of safety it is a matter of some importance. In a machine-made wood-stave pipe there is a banding which has been machine-placed and each time the line is subjected to excess pressure a slight compression of the wood occurs under the bands so that we eventually have a line that becomes leaky and cannot be satisfactorily brought back to a tight condition, due to this excess and unanticipated starting condition, and to a similar condition occurring at shut-down.

1. Journal A. I. E. E., Vol. XLIII, November, p. 1042.

When a centrifugal pump stops it stops quickly, and the check valve closes and a surging occurs which produces, sometimes, double normal pressure, and which repeats for a long time. But this can be taken care of by the introduction of an air chamber which will produce control, while the excess at starting has to be taken care of by the introduction of a different type of starting apparatus. Although these motors are small as compared to the capacity of the system; they are frequently from 100 to 250 h. p. and require starting devices of considerable size.

PRACTICES IN TELEPHONE TRANSMISSION MAINTENANCE WORK[1]

(HARDEN)

TELEPHONE CIRCUIT UNBALANCES[2]

(FERRIS AND MC CURDY)

PASADENA, CAL., OCTOBER 17, 1924

D. I. Cone: To the engineers and maintenance people of the operating telephone systems these advances in the means for maintaining the circuits are very gratifying. There are two major reasons for their need: First, in order to employ economically the communication plant, as many types of service as possible are put on the wires. Balancing the circuits is one means employed to separate one channel of communication from another. Second: The growth of power circuits and their inductive fields has been so great that communication circuits, which originally had the field very much to themselves, are now forced to exist in the presence of large inductive and conductive fields. Since the same people want both power and communication service it is impossible altogether to prevent that. The original telephone circuits would be wholly inoperative under present-day conditions but for the advances made, on the one hand, by the method of balancing the communication circuits, and on the other hand, by measures taken in the supply circuits to limit their fields of influence.

The Pacific Telephone & Telegraph System has about 3000 toll circuits, which it is our duty to maintain in efficient operating condition. Mr. Harden has described to you the testing technique employed for transmission maintenance. As a part of this we have, for several years, been making annual noise tests on these toll circuits, in addition to special tests made at times when changes either in the telephone circuit or in the neighboring power circuit are made, and acceptance tests of new circuits. When the crosstalk meter, which Mr. Ferris described, became available, measurements with it to determine the condition of the circuits were incorporated and are now regularly made as a part of our routine.

Since the impedance-unbalance bridge became available some years ago, we have made much use of it in locating unbalances of the types mentioned, particularly resistance unbalances and transposition irregularities. In this Pacific Coast toll network we have several hundred thousand circuit transpositions whose maintenance is a large problem. It would be possible to present to you many curves obtained on our circuits, similar to those shown in Figs. 9, 10, 11 and 12 of the paper, but these illustrate so well the characteristics obtained and the ability of this apparatus to show the nature of unbalances that it seems unnecessary to add more examples.

Referring to Fig. 10, where an artificial unbalance was inserted at a known distance, it is easily possible, by the formula given, to calculate the velocity of travel of the waves in that circuit. This was a loaded cable circuit and I find the velocity to be 7900 mi. per second. That is very different from the velocity in the open wire lines and we find it desirable to take account of this difference of velocity in cables and open wires when we are testing circuits which enter the office through long toll entering cables. The setup given in Fig. 10 affords a means of obtaining a "calibration" of the velocity factor.

To illustrate the necessity for obtaining balance, not only where there are inductive exposures, but throughout the line, suppose a line into which a branch line connects, the branch line being exposed to a source of noise. The induced energy will flow into the main section of the line and if there are unbalances on this main line, we will have trouble from the exposure, even though perfect balance were obtained on the branch circuit.

It might be asked, what is the relation of these more recent methods to the previously available working methods used? The advance seems to me to come in the form of a very definite improvement of technique. The impedance-unbalance bridge represents the application of alternating current at varying frequencies to the old familiar Varley loop test much used for location of faults with the Wheatstone Bridge. Using the same idea, but a variety of alternating-current frequencies, it detects effects which the direct-current bridge cannot discover.

We often make use of the induced noise voltage to ground, comparing it with the induced voltage between wires. That has served as a rough method of indicating balance, which had some usefulness, employing the source of energy which happened to be there in the form of the disturbing circuits. On the other hand, in the methods here described, we have a definitely controlled and applied source of energy, with its manifest advantages.

By the pursuit of the methods indicated in the paper in providing and maintaining a high grade of balance in the telephone circuits important reductions in noise and in crosstalk have been realized in our plant. To offset this we have been confronted with the rapid expansion of the power circuits. That it has been possible to improve the conditions has been due to the faithful efforts of a large group of men. Having devoted their energies to the solution of this problem, they have enabled us to make remarkable advances in this direction. I feel moved to pay tribute to the work of these men because of the exceptional hours at which they often have to work in order that the normal service of the communication and power circuits may not be interrupted.

H. W. Hitchcock: In regard to the value of adequate transmission maintenance, such as is described in Mr. Harden's paper, I think it quite obvious that in the case of a toll circuit which involves an investment of possibly several thousand dollars, it is extremely important that the circuit be kept in a high degree of efficiency, as we can hardly afford to lose a considerable portion of its volume efficiency by allowing small troubles to creep in. As this is quite evident, it needs no further elaboration and I shall confine my further remarks to a discussion of the advantages to be derived from proper transmission maintenance in the local exchange plant where its value perhaps is not so apparent.

Unless one has given the matter close consideration, he may have the idea that a telephone plant grows in a more or less haphazard way. In fact, we set up quite a definite transmission standard of efficiency, which applies to the entire plant. That is, we attempt to make it possible for every subscriber to talk to every other subscriber with approximately the same degree of efficiency. This standard of efficiency has been arrived at from a study of extensive laboratory tests and from trying out certain standards in actual practice. In the latter case, particularly, the result is a combined reaction from a large number of people having all kinds of ears and voices and personal temperaments.

As a result of years of experience and trial, we have established a standard which we call a twenty-mile standard. "This means that the telephone circuit to give good transmission can have the same loss as that produced by 20 miles of standard 19 gage cable. This standard is possible because the modern telephone transmitter produces in the circuit, telephone currents representing an amplification of several hundred times over the acoustic power directed by the voice against the transmitter

1. JOURNAL A. I. E. E., Vol. LXIII, December, p. 1124.
2. JOURNAL A. I. E. E., Vol. LXIII, December, p. 1133.

diaphragm and therefore for satisfactory telephone conversations the telephone power delivered to the receiver at the far end of the circuit need be only a fraction of 1 per cent of the input power at the transmitting end. The fact that the overall electrical efficiency of the circuit itself is low is not of importance as we are dealing in the ultimate with the overall efficiency from the voice of the speaker to the ear of the listener. Furthermore, a very small amount of acoustic power at the receiving end is sufficient to give a very clear conversation and when you are talking with a person over the telephone you are anxious to make him understand what you have to say; you are not trying to warm up his ear."

Disregarding, for the present, the matter of cost, the proper volume of efficiency might be arrived at somewhat as follows:

Two telephone instruments might be connected together with a very short circuit and speech exchanged over them. In such a case, it would be found that the volume of tone would be unnecessarily loud, in fact it would be something like trying to talk to another person if he insisted upon shouting in your ear. The circuit between the telephones might then be extended until the speech became very weak and made it necessary to listen very closely and possibly ask that the speaker shout or repeat frequently in order that the speech might be understood. Obviously, a circuit having some intermediate efficiency would be preferable to either of these, and the one which, on the whole, would give the best results could be determined by repeated trial.

In establishing a standard, however, the economic factor cannot be ignored. The more power which you transmit over a circuit of a given length, the more copper you must place in it, with a corresponding increase in cost. From an economic consideration, then we would use the smallest wire which it is possible to employ and still transmit understandable speech.

As a result of these somewhat conflicting requirements, we select a standard which we believe will give good speech transmission, enabling one person to talk to another without unnecessary repetition and without having to shout, and at the same time provide the service at a price which will make it attractive for him to use freely.

Having established such a standard, it is obviously poor economy to depart from it in either direction. To do so tends to limit the service, to discourage its use, or make it unsatisfactory to the public. This will result on the one hand, from too great a cost if too high a degree of efficiency is attempted, and on the other, from poor and unsatisfactory transmission if a circuit of insufficient efficiency is provided.

In the design of a telephone plant, we usually assume approximately one hundred per cent efficiency for all the parts which go to make it up. Of course, it is impossible to expect that such parts will always be, and remain indefinitely, at this high degree of efficiency. Troubles are bound to creep in, just as they creep into any plant, so that we must face the fact that our plant tends to deteriorate, or that we will occasionally find defective instruments, such as transmitters, receivers or other parts. There are in general two ways by which this deterioration can be cared for. One is by providing a margin of safety in our plant design sufficient to make up for these occasional defects. The other is to detect these troubles as they arise and remove them. I believe it is obvious to all of you that the first method is not a very satisfactory one. It means that the entire plant must be much more expensively constructed than would otherwise be necessary. Moreover it is not satisfactory from the subscriber's point of view. For example, a subscriber's instrument may, for some reason, have deteriorated until it only is ten per cent as as good as it should be. He reports it and the company sends an adjuster to discuss the matter with him. The company's representative may say to the subscriber: "We appreciate that your set may be in very poor shape; in fact, it may only be ten per cent as good as it should be. To offset this, however we have designed your circuit, and those of your ten neighbors' lines, ten per cent better than we think is necessary, so that the average efficiency of our plant is satisfactory: nine instruments are ten per cent better than is necessary as against one instrument which is only ten per cent as good as it should be." The reaction of such an individual is obvious. He would reply that this is very nice for his neighbors perhaps but is of very little benefit to him.

In order to make such a method effective, it would be necessary to have all of the instruments several times as good as would normally be required and this would be prohibitive in expense. When we provide only a small margin of safety to take care of isolated cases of trouble, we fail to accomplish the thing which we set out to do. The only way, then, is to detect these troubles as they appear and clear them promptly. Unfortunately, for the telephone company, they do not always announce themselves. Some of them, of course, do, such as "opens," "grounds," "crosses," or troubles of that kind. In these cases the supervisory signals fail to function or it is impossible to talk at all or the circuit is very noisy. Such troubles quickly call attention to themselves and are promptly remedied.

Another class of trouble is one which may produce only a moderate reduction in efficiency such as a few short-circuited turns on a coil or a partially defective condenser or a high-resistance joint. Such a circuit will usually give the proper supervisory response and can be talked over with a certain degree of facility. However, should such troubles be allowed to remain they will cause a gradual deterioration in the plant with a corresponding increase in the number of unsatisfactory connections. The only way to detect such trouble is by a series of systematic tests conducted periodically which cover the entire plant. In this way we find the troubles which are hidden away and which will not appear on ordinary inspection or as a result of the usual maintenance tests. To make such tests it is necessary that special instruments and routines be developed and followed and it is these tools, these instruments, these methods, which Mr. Harden has described and which we now have available for this kind of work. These new facilities are of tremendous value to us as you can well appreciate since they make it possible to give a good and uniform standard of service with a plant designed with the maximum degree of economy.

Farley Osgood: I might just say a word on the matter of inductive interference. I think it is the duty of the power engineer to make known any contemplated plan he may have for construction to his telephone friends as soon as it is practicable for him to do so. A number of years ago the lines were built without due consideration to any neighbors and the problem of interference got to be more and more a disturbing one, until its seriousness was recognized and committees formed to deal with it. These committees, the National Electric Light Committee and the Joint Overall Committee, with men from both groups, worked out a most friendly relationship all over the country and the basis of it all is to confide in each other any plans of construction, of course, with the understanding that there will be no propaganda about the plans. The engineers of the two properties should know each other's plans at the start in order that disturbances may be avoided by injecting into the construction program the present known methods of elimination.

V. D. Elliot: I think, that the men who are employed by the larger power companies, particularly those which have extensive private telephone systems, could, with advantage to themselves and to their companies, become more familiar with the subjects treated in these papers. I know that a number of these instruments, if not all of them, could, with certain modifications, be used for testing work on the private telephone systems of the large power companies.

I wish to say, by way of appreciation, that the telephone men of Southern California have shown a cooperative spirit to the Edison Company, by giving helpful suggestions, loaning appara-

tus and offering their help in any way possible to aid us in following out these ideas on our system.

It may be of interest to some of the telephone men and, perhaps, to the power men to know of a case of telephone line balance, which occurred on the telephone system of the Edison Company.

The telephone lead, which was built for the operation of the Big Creek System of the Southern California Edison Company, as originally constructed, had four wires, carried on a pole line separated by varying distances from the 150,000-volt power circuits. It was never intended to be other than a two-circuit line as the cross arms were of such size as to accommodate only the four wires, and the transposition system was only designed to take care of cross talk balance between the pairs.

When we started construction work on raising the Big Creek Dams there was need for an additional circuit from our Los Angeles office to Big Creek. I was asked to see if a phantom circuit could be installed without great expense. We put on phantom coils at the two ends and made a trial and found that we could operate without undue crosstalk, without any phantom transpositions. The line has been rebuilt in certain sections and phantom transpositions have there been installed and provisions have been made to accommodate any number of future wires and also to take care of any outside induction that may be present. Exclusive of these places there are 100 to 150 miles of the lead which have no phantom transpositions, but the crosstalk and noise on that phantom circuit is tolerable from our standpoint and we can carry on a conversation and without interfering with the talking on the side circuits.

This I think is a different experience from that which the telephone men have had and I thought it might be of interest to them and also to the power men who have telephone circuits and are contemplating the use of phantom circuits.

Four years ago we superimposed a simplex telegraph circuit on top of the others and it is operating successfully without interference with the other channels.

Mr. Ashbrook, of our company, has tried out recently, in an experimental way, apparatus for stopping, or minimizing acoustic shocks which occur on these telephone circuits due to flashovers on the power lines. The power line is in general proximity to this line for its entire length of 241 mi. At some places the lines are 8 mi. apart and in other cases they run parallel at 1000 ft. separation, but in general the average horizontal separation is about one-half mile. At times of flashover currents as high as 900 amperes going from the power circuit with a ground return, create a large magnetic loop which induces considerable voltage between ground and the telephone line. This voltage has a very steep wave front and part of it appears as a voltage between wires due to unavoidable telephone line unbalances resulting in an acoustic shock or "bat in the ear."

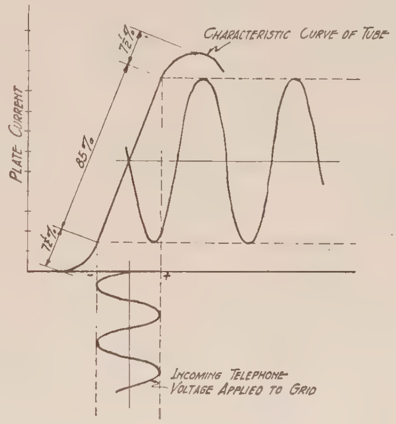
Mr. Ashbrook has a method to overcome this effect, but we do not know as yet whether or not it will be applicable as a regular adjunct to the telephone system.

R. B. Ashbrook: The vacuum tube is utilized as a voltage-limiting device by operating the vacuum tube at such a point on its static characteristic curve that the voltage produced by normal telephone communication and applied to the grid causes a change of plate current over approximately 85 per cent of its characteristic curve. It is obvious that 7½ per cent increase in negative voltage will result in the plate current being reduced to zero and further increase will have no effect. If the increase is in the positive direction the plate current will increase until the saturation current corresponding to the existing filament temperature is reached. Further positive increase in the grid potential cannot result in further increase in the plate current, in fact as it becomes more positive it attracts a greater number of electrons to itself and causes a corresponding decrease in plate current.

A recent demonstration has proven beyond a doubt its usefulness to power companies operating telephone lines subjected to between-wire voltages occasioned by energizing or de-energizing paralell transmission lines.

Two operators, one a student wearing an operator's head set equipped with the acoustic-shock-suppression apparatus, the other with the usual operator's telephone set were connected with a telephone line at the time that a transmission line failed. The operator received a severe acoustic shock which was very painful and necessitated doctor's care for several days before resuming her duties while the student operator was not positive whether she heard it at all.

J. E. Woodbridge: The work of the Department of Development and Research of the American Telephone and Telegraph Company on the lines described in this paper is of vital importance to the settlement of the problems of inductive interference which confront two divisions of the electrical industry. Such work is essential to the establishment of precise rules for legislative enactment in this controversy where such legislation is found necessary.



This is for the following reason:

A telephone circuit balanced in all respects, including balance to other circuits, is immune to inductive interference.

The real difficulty is, of course, to get such a balanced telephone circuit. An equally real difficulty in the past negotiations between the two interests has been to get either a criterion of unbalance, or a means of measuring the unbalance of communication circuits.

At the time when the Joint Committee on Inductive Interference, appointed by the California State Railroad Commission, was struggling with its problems, namely, from 1913 to 1917, the Committee members recognized the importance of the balance of telephone circuits, and that the legislation based on the Committee's findings ought to include rules on such balance so that undue diligence for the mitigation of interference should not be put upon the power systems. The difficulty, however, of measuring unbalances or of defining practicable balance made it impossible to include in the code any quantitative rules for limiting unbalances of telephone circuits.

This difficulty has now been partially removed by the work outlined in this paper. It is to be hoped that the work will be carried further to determine and make it possible to define reasonable or practical units of unbalance that can be specified as limits or tolerances in commerical construction and operation.

R. G. McCurdy: Mr. Cone referes to a method of measuring unbalances by determing the ratio of the noise measured in the metallic telephone circuit to the noise voltage measured to ground. While this test is valuable as preliminary indication it is generally not conclusive, because as mentioned in the paper, the noise measured in the metallic circuit includes two effects; one dependent upon unbalances of the circuit in its

relations to ground and other telephone circuits, and the other dependent upon the dissymmetry in its relations to parallel power circuits. If this ratio indicates a high voltage to ground and a low noise in the metallic circuit, we are justified in concluding that the circuit is well balanced. If, however, the ratio is in the opposite direction, it may be concluded either that the circuit is unbalanced or that relatively large voltages are induced in the metallic circuit because of dissymmetry to parallel power circuits. Thus, in order to obtain any definite indication of the existence of unbalances of the circuit to ground or to other telephone circuits, tests must be made under controlled conditions, as described in the paper.

Mr. Elliott brings up the case of a line with a single phantom group, which was in a satisfactory condition from the standpoints of crosstalk and noise on both the side and phantom circuits with no transpositions in the phantom circuit. It should be observed that when no other circuits are nearby, complete balance may be secured between the two side circuits and between each side circuit and the phantom, provided each side circuit is made up of wires of the same size and with transpositions placed only in the side circuits. If any more telephone circuits are added to the same line, or if power circuits are constructed in proximity, it then becomes necessary to consider the balance of the phantom circuit. Under these conditions, all four wires of the phantom group must be of the same size and transpositions must be placed in the phantom circuit. I take it, in the case discussed by Mr. Elliott, no close exposures existed to other circuits.

L. P. Ferris: The use of the vacuum tube as an energy-limiting device referred to by Mr. Ashbrook has long been recognized by telephone engineers and has been proposed specifically for this purpose (H. D. Arnold, U. S. Patent No. 1168270, January 18, 1916). The telephone repeater in common use in many of our long telephone circuits employs vacuum tubes, and of course possesses this energy-limiting characteristic. Application of this method was considered a number of years ago in a case of parallelism between a telephone cable and a power circuit, which at times of short circuit caused acoustic shock to telephone operators. The large number of telephone circuits to be protected made the cost of vacuum-tube terminal equipment practically prohibitive. Other methods were found effective and more economical. It is, however, a different matter where only one or two circuits are involved as on a power company's private dispatch line.

Mr Woodbridge has stated that "a telephone circuit balanced in all respects, including balance to other circuits, is immune to inductive interference." This is theoretically true if the induced voltages to ground are not large enough to endanger personnel, break down insulation, or operate protective devices. Voltages high enough to interrupt service may be induced, even though the circuit be balanced in the manner Mr. Woodbridge suggests. Without exception, however, it might be said that a power circuit balanced in all respects, including balance to other circuits and its mode of energization, would cause no inductive interference. Both conditions are ideal but unrealizable in practise and, therefore, largely of academic interest. Balance of both systems, power and telephone within themselves, and with respect to each other, is important in preventing interference. Practically useful definitions of unbalance must, however, recognize these three distinct problems—balance of each system within itself, and mutual balance in exposures. Aside from the undesirable technical complications involved in making the unbalance of one system dependent upon the condition of the other, the importance is apparent from an administrative standpoint, of placing upon each party the responsibility for maintenance of its system in balance, only so far as conditions are under its control. This reduces the zone of joint responsibility to its minimum dimensions; *i. e.*, to the section where the two systems are in relatively close proximity, the exposure, which in general, involves but a small part of each system. Here responsibility for balance is inherently joint or divided, a situation not to be unnecessarily extended. It was with a background of such practical considerations in mind that our definition of a balanced telephone circuit was formulated, and in the opening paragraphs of the paper it is pointed out that it deals only with unbalances of the telephone circuits themselves, independent of their relation to power circuits. Thus, the problem of mutual unbalance within exposures, largely a problem of coordinated transposition design, and the problem of power-circuit balance, were purposely excluded from the scope of the present paper. This, of course, does not mean we feel them any less important than the problem considered.

Mr. Woodbridge referring to the work of the California Joint Committee on Inductive Interference, mentions the difficulty then recognized of getting a criterion and measure of unbalance, and of setting any quantitative limits. The authors were associated with Mr. Woodbridge in this early joint work and as an outgrowth of the need then developed, the investigation reported in this paper was undertaken. That the results have been put into effective use on the Pacific Coast, it is gratifying to note from Mr. Cone's discussion. We recognize and have so stated in the conclusion of the paper that not all has been done along this line and with the joint development and research work now under way with power engineers, we hope as does Mr. Woodbridge that it may be possible to specify practical tolerances in construction and operation.

ELECTRICAL EQUIPMENT OF CONSOLIDATED MINING AND SMELTING COMPANY'S ZINC PLANT[1]

(LOCKYER)

PASADENA, CAL., OCTOBER 16, 1924

W. S. Peterson: I was employed at the plant referred to in this paper, which has rotary converters for its source of direct current. My experience at that plant, was that the rotary converters justify themselves in every way. The losses saved were roughly 5 per cent or 6 per cent of the total power used. The total power was 35,000 kw., which was maintained for 24 hours per day. You can understand that the power saved more than makes up for the increased maintenance of the rotary converter. The final result is greater economy.

I will now explain the use of the motor-generator set to hold the zinc from redissolving into the solution, when the rotary converters were off the electrolyzing tanks. The plant was originally laid out for five tank circuits, with six rotary converters, thus allowing one spare. Due to the necessity for greater production at one time, the plant was operated with six sets of tanks on the six converters, with no spare. The company had some motor-generator sets from an electrolytic copper refinery, which they were not using, and therefore installed them to use temporarily on a tank circuit while a rotary converter was down for repair work. This change probably worked out better than to have another rotary converter, due to the fact that the rotary converters in actual operation were down for repairs and maintenance not much over 1 per cent and certainly less than $1\frac{1}{2}$ per cent of the total time. The main loss in a shutdown was not only the loss of production but the loss due to redissolving of the zinc. By having the motor generator carry one-third to one-half of the normal tank load, this latter loss could be avoided.

In the early years of the operation of this plant there was considerable trouble with the converters due largely to the lack of experience of the operators. For the past three years, I am told, the operation has been such as to give nearly 99 per cent availability per machine which seems remarkably good. Some may feel inclined to disbelieve this, but this record is taken over periods of nine or ten months continuous running at a time

1. JOURNAL A. I. E. E., Vol. XLIII, June, p. 531.

when there no spares due to full production being required. A rotary would be taken down once every week or ten days for cleaning and overhauling the brushes.

I would say from my experience with this kind of a plant, that the synchronous converter certainly deserves its place there due to its economical operation and is to be considered far superior to the motor generator for that work.

STREET LIGHTING—A MUNICIPAL PROBLEM[1]

(Whitney)

Pasadena, Cal., October 17, 1924

C. J. Stahl: Mr. Whitney has spoken of the Joint Committee on street lighting appointed by the New York State Conference of Mayors in cooperation with the Empire State Gas and Electrical Association. Apparently, this committee has felt the desirability of establishing a practical nomenclature in which street-lighting values may be expressed in recognized terms. This idea is commendable and no doubt some progress has already been made. However, we may meet difficulty in using the term lumens per square foot as a measure of illumination if the total lumens output of the lighting unit is to be used instead of the actual lumens applied to the surface of the street. The latter criterion would give the credit due to equipment which utilizes the output of the lamp to better advantage. An upright diffusing ball globe for example, produces practically a uniform distribution in both horizontal and vertical planes with slightly more light above the horizontal than below. Other units employing reflectors or refractors increase the light in the lower hemisphere and distribute it symmetrically over the surrounding area. Still other designs control the light both in the vertical and horizontal planes resulting in still higher illumination on the surface of the street.

It seems we are fundamentally in error in the purchase and sale of street-lighting services. Most contracts provide rates based upon power consumption instead of light delivery. When a central station makes such a contract it is naturally disposed to favor equipment of low first cost and maintenance charges in order to make a fair profit or to break even, for much street-lighting business is still being taken on a profitless basis. This means that there is naturally a strong tendency to use cheap, inefficient equipment. In a unit such as the ball globe, giving a uniform spherical distribution there is no duplication of glassware by the addition of refractors and no elaborate mechanical parts to support reflectors. Therefore, such units can be furnished at a low first cost. On the other hand the cost per unit of illumination is high when compared with the cost of the additional light obtained from modern equipment using efficient methods of light control. Such equipment would be given due credit if rates were fixed for the delivery of certain average values of illumination. We might also specify the minimum variation factor or the minimum and maximum values of illumination permissible in producing certain values, otherwise satisfactory uniformity would not be assured.

Specifications can be made to insure the desired aesthetic effects as influenced by the spacing arrangement, mounting height and other design features. The central station would then be at liberty to deliver the required illumination by the use of lamps of sufficient size to make up for inefficiency in cheap equipment or by using modern equipment of high efficiency thus permitting the use of smaller lamps.

Some one may say that such a procedure is predicated on the assumption that the street surface is the only area we need take into consideration. Such an assumption would of course be fallacious. In residential districts some illumination is desired over the area surrounding homes and in business districts the building fronts should not be left in darkness. However, with the most effective media of control, as represented by the most efficient units now availbale, these requirements are adequately met. Our efforts to direct the light primarily to the street surface result in substantially enhanced illumination, however, try as we may we cannot by practical means directionally control the output of the lamp so completely as to neglect harmfully the secondary requirements of surrounding areas.

Present-day street traffic demands illumination on the street surface far in excess of that required ten years ago. On the other hand sidewalk traffic and pedestrian traffic in general is little, if any, faster than ten years ago. There are numerous other reasons why primary considerations deal with the street surface and everything considered an asymmetic distribution seems entirely practical and desirable. It is, therefore, plain that lumens per square foot of street, if we base our relation on the lumens output of the lighting equipment, without reference to direction, does not give us a true measure of street-lighting service. Other things being equal, which assumption must also hold if we speak in terms of lumens, the foot-candle would seem a more logical measure for it definitely expresses the service rendered. When we speak with the layman on matters of interior lighting the foot-candle is our yardstick. We must, therefore, hope that, in time, the foot-candle as a measure of illumination may be understood and used by the public at large. We readily visualize a foot or a yard but only these versed in light and illumination have a fair conception of the degree of illumination represented by the foot-candle. A general recognition and proper conception of this unit may be regarded as one essential to be accomplished by current and future educational work. Such work would be more difficult and results retarded if we are to expect the layman to speak in terms of lumens per square foot in street lighting and in foot-candles when considering the lighting of interiors. This should not be overlooked in establishing a unified nomenclature.

R. D. Whitney: In answer to this, I would say that I advocate neither system. If all will agree to cut out the lumens, I would be satisfied but I do not wish to struggle with both.

O. F. Haas (by letter): Under the heading "Practical Considerations," Professor Whitney indicates that the standardization of ornamental street-lighting equipment throughout a city is not the most desirable practise. It seems to me, however, that to insure that the street lighting in any city will be developed according to the best engineering principles it is necessary that a comprehensive street-lighting program be developed classifying or zoning the various streets depending upon the lighting requirements.

This complete and unified program tends to lift street lighting out of the class of political footballs, and I believe, insures the most satisfaction per dollar expended. Such a comprehensive program, of necessity, must be prepared by engineers whose knowledge results in an installation with the proper balance between initial cost, maintenance, efficiency and appearance. Visitors are impressed by the unified appearance of the design and the citizens are even more pleased for costs are reduced not only through the choice of efficient equipment but also because of less equipment to stock and the standardized handling of construction and maintenance work.

The work of the New York State Committee is to be highly commended. The growing tendency to apply sound engineering principles to the solution of street-lighting problems is most gratifying. With the thought of studying the most effective manner of distributing light on the street the Municipal Department of Light and Power, the Cleveland Electric Illuminating Company, and the National Lamp Works have installed at Cleveland a full-scale street laboratory for investigating and demonstrating the principles underlying thoroughfare and residential street lighting.

The installation covers a 2000-ft. section of a typical Cleveland street, East 152nd Street. It consists of some forty separate lamp circuits—virtually forty streets in one—and each circuit illustrates a definite principle of correct illumination. Lamps ranging from 1000 lumens to 30,000 lumens in size, with

1. Journal A. I. E. E., Vol. XLIII, December, p. 1148.

spacings from 75 ft. to 900 ft. are mounted at heights from 11 ft. to 26 ft. The location of units ranges, by four successive steps, from 2 ft. back of the curb line to the center of the street, bracket arms being used.

This installation affords by far the most comprehensive demonstration of street-lighting principles and effects ever installed. It is the only place in the world where comparison of a wide variety of lighting effects upon the street can be made instantly. It is planned to conduct a number of investigations under the various lighting effects for a wide variety of conditions, with the view of properly evaluating the different factors involved and obtaining definite information regarding the particular characteristics of each system.

This installation will also serve another distinct purpose, apart from its research function. The selection of a suitable street-lighting system by a town or city has always been rendered somewhat difficult on account of the lack of an opportunity to view a number of different street-lighting systems at one time and to compare their characteristics with respect to the specific requirements of that town or city. With this demonstration available at Cleveland, engineers, city officials, and civic organizations now have an opportunity to view at one time the various standard types of street-lighting systems that are available in order to compare their individual characteristics of appearance and light distribution.

R. D. Whitney: Those present may be interested in the way we finance street lighting in the East, as I understand it is quire different from what is done out here.

It is difficult to get a city administration to maintain satisfactorily a street-lighting system. In Syracuse the street lighting is purchased from the operating company at an annual charge for each unit. The City of Syracuse does not own any of the equipment. A 2500-lumen lamp, the smallest which is installed, mounted on a bracket from a wooden pole costs $30 per annum; the 4000-lumen lantern, post-mounted, costs $65; the single-lamp inverted magnetite, $90; and the twin-lamp standard of this type $165.

Considerable dissatisfaction with the present method of financing an ornamental lighting installation is experienced. By State Law for cities of the second class, the abutting property must pay 50 per cent and the city at large 50 per cent with assessment on a valuation basis as other taxes are levied. This means that the property owners on the streets where values are greater pay not only for their own lighting but a large proportion of that for the minor streets. Assessment on a front-foot basis will no doubt be effective in the near future.

It has been interesting in studying street-lighting systems in the East to observe the great diversity of opinion among those responsible. One engineer will tell you that "No living man can operate an arc lamp satisfactorily." The next city you visit has no parkway cable in its system and will not have as long as the personnel of those interested does not change. One of the points least considered is careful spacing of standards.

The most important thing in street lighting is conceded by some to be the spacing of units. In Syracuse, intersections are not ignored. Accidents usually occur at intersections and these should, therefore, be adequately lighted and the other units arranged accordingly.

In Rochester last June, our street-lighting exhibit consisted of twenty-one different types of installations on the city streets. Over 200 city officials viewed these installations in a 12-mile ride. Our report had been given prior to this inspection trip. All interested were asked to co-operate in this exhibition and several special blocks were set up. The City of Rochester is very well lighted and has some 30 mi. of ornamental lighting.

Farley Osgood: I would like to ask if, in laying out your lighting systems you give consideration to the possible interference with communication systems?

R. D. Whitney: In Syracuse our communication systems are underground in most of the streets where special lighting has been installed. Our greatest interference has been with traffic signals. An effort was made to use the same poles for the lighting and signals but this was later abandoned. Poles of the same design are used for the traffic signals, four at each intersection, and the latter system is entirely independent. Thirty-two street intersections are to be controlled automatically and simultaneously.

Street-lighting systems are producing considerable interference with radio reception. Some operating executives have told me that they welcome such complaints and feel that their systems are operating more efficiently as a result of these reports.

L. P. Ferris: I should like to ask if you employ individual transformers with your incandescent lamps?

R. D. Whitney: We have no individual transformers. We use a straight series circuit and at present each circuit begins and ends at each of our two substations.

L. P. Ferris: That is a very much better condition with respect to interference and perhaps accounts for the fact that you have not heard of complaints that you might have otherwise. We have run into cases of individual transformers supplying the lamps at a higher current than 6.6 amperes and when those lamps burn out it leaves the transformer secondary open and the over-saturation of those transformers has been known to produce a harmonic sufficiently high to interfere, not only with the ordinary communication circuit, but in some cases with radio.

R. D. Whitney: The discussion has served to emphasize the need of a comprehensive city-wide street-lighting program and the need of real engineering in laying out such systems. In the East, many cities are awakening to this and the report given at Rochester before the annual Mayor's Conference last June has already borne fruit in a number of New York State Cities. Street lighting is beginning to take a more important place in city planning and let us hope that it will receive more consideration in the future.

HYDROELECTRIC DEVELOPMENT IN CANADA IN 1924

The Minister of the Interior in his annual statement regarding the development, distribution, and use of hydroelectric energy in Canada reports an exceptionally substantial growth during 1924. More than 300,000 horse power of new installations were added during the year, involving some $45,000,000 in capital expenditure and bringing the total installation in the Dominion to 3,569,275 horse power. This does not, however, give a complete picture of the situation, as many large projects were carried well toward completion and will, when finished in 1925, bring a further addition of 600,000 horse power to the country's total.

Installations by Provinces

Installations in the various Provinces during 1924 were: Quebec, 175,000 horse power; Ontario, 132,000 horse power; and Nova Scotia, approximately 7000 horse power. In British Columbia, no new installation was completed during 1924, but extensive developments were being carried on by the British Columbia Electric Railway Co. and the West Kootenay Light and Power Co. It is expected that these installations will be completed during 1925.—*Commerce Reports.*

ILLUMINATION ITEMS

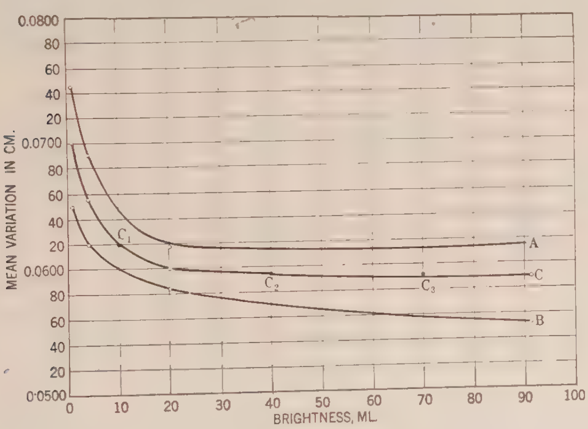
By the Lighting and Illumination Committee

THE EFFECT OF BRIGTHNESS ON THE PRECISION OF VISUALLY CONTROLLED OPERATIONS

By P. W. Cobb and Frank K. Moss*

The possibilities of increasing production in industrial plants by the use of better designed lighting equipment and higher intensities of illumination have been proved experimentally and in practise. In general, such changes in the lighting of a factory have been made for the purpose of increasing production. There are many operations, however, where the accuracy with which piece of work can be done is of more importance then the speed, and the advantages of better lighting can be utilized in promoting accuracy rather than in saving time. Of course, this increased accuracy may result in increased production.

The relation between brightness and precision was investigated in the Lighting Research Laboratory at Nela Park by requiring a number of subjects to set a movable marker opposite a fixed one, working under several different intensities of illumination. In order to realize the full advantage of better lighting in



Curves *B* and *A* give the relation between brightness and the mean variation of the settings for light and dark surroundings respectively. Curve *C* is the average of curves *A* and *B*; points C_1, C_2, and C_3 were obtained by interpolation.

precision and not in *speed* a definite amount of time (two seconds) was allowed for each adjustment of the apparatus. The mean variation from the mean setting was chosen as the criterion for the precision of the work. The experimental results, of which there are some 25,000 individual settings obtained with ten different subjects, are shown plotted in the accompanying illustration.

Four values of brightness, 1, 5, 20 and 100 millilamberts were used so that the data includes practical levels of intensity. (This range in brightness corresponds to a range in foot-candles on a surface of 80% reflection-factor from .86 to 86 foot-candles approximately). Curve *B* is obtained by plotting the mean variation against the brightness when the field surrounding the test-object was illuminated to the same intensity as the back-ground of the test-object. Since the ratio of the brightness of the background to the surrounding field was known to be an appreciable factor in visual work, the experiment was repeated, having the surrounding field dark. The effect of the dark surroundings was to increase the mean variation of the settings although the same intensities on the test-object were used in both cases. Curve *A* represents this latter condition. Curve *C* is the arithmetical average of Curves *A* and *B*.

The curves appear asymptotic but other considerations indicate that there are limits with respect to both variables. At or below threshold values of brightness the setting would be made largely by touch or muscle sense, with vision a much less important factor. At extremely high intensities a falling off of precision would be expected as the result of "glare," especially when the test-object appears as a bright area in a dark field, An intimation of this effect is to be seen in curve *A*. although this would by itself not be conclusive evidence.

It is reasonable to assume that with test-objects of other descriptions a similar relation between precision and brightness would be obtained, and therefore, that the general result obtained is fundamental and not a function of the particular apparatus used.

The results of this investigation can be applied to many industrial operations. In cases where the output is on a quantity production basis with the various operations following one another at fixed and predetermined intervals, the conditions encountered parallel those of the test and the gain in accuracy found in the laboratory could be expected in practise.

*Both of the Lighting Research Laboratory, National Lamp Works, General Electric Co., Nela Park, Cleveland, Ohio.

SCHENECTADY'S WHITE WAY

"Ornamental lighting standards on every paved street" is the verdict of Schenectady, N. Y., which has made Erie Boulevard, one of its main thoroughfares, the best lighted street in the eastern part of the country. With the "Path of Gold" of San Francisco and the business section of Salt Lake City, it ranks among the three best lighted streets of the world.

A few years ago, when the newly completed Barge Canal caused the abandonment of the old Erie Canal, Schenectady was faced by the problem, how could the old canal bed be utilized to the best advantage?

Plans were made for the construction of a boulevard across the city—a direct route from the center of the business section to each of its largest manufacturing concerns.

One section of the boulevard has been completed—113 feet between curbs, with twenty-foot sidewalks, parkways and underground wiring. On the eve of the Fourth of July, a switch was thrown in the power station, and Erie Boulevard burst into a splendor of light fifty times as bright as that to which it had been accustomed.—*Lighting Fixtures and Lighting*.

JOURNAL OF THE American Institute of Electrical Engineers

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GEORGE A. HAMILTON, *Treasurer* F. L. HUTCHINSON, *Secretary*

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

St. Louis Ready for Spring Convention

Interest continues to increase in the Spring Convention in St. Louis, April 13-17. The large and energetic local committee has perfected all details of the arrangements. A technical program of high order will be presented. The subjects of the papers will

ENTRANCE TO CHASE HOTEL, ST. LOUIS

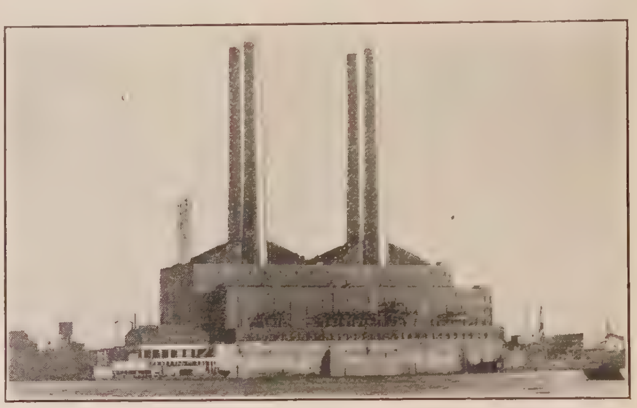
be of especial interest to those who are located in the central section of the country. Included in the topics will be power stations and systems, electrical machinery, communication and marine, mine and industrial applications. The list of papers will be the same as that given in the announcement in the March issue of the JOURNAL, page 305, with the addition of one paper, namely, *Electric Shovels* by D. J. Shelton, Marion Steam Shovel Company, and D. S. Stoetzel, General Electric Company.

COMPLETE PLANS FOR LADIES

The social and sports events have been emphasized in making arrangements. Special and complete plans have been made for the pleasure of the ladies and the attendance of a large number is expected.

OBTAIN REDUCED-FARE CERTIFICATES

All those who attend from outside of St. Louis should without fail obtain railroad certificates when purchasing tickets. These certificates entitle the holders to half-rate return fare over the same route as that used in going to St. Louis, provided 250 certificates are turned in at convention headquarters in St. Louis.



POWER STATION, UNION ELECTRIC LIGHT AND POWER CO.

The help of every visitor is needed to insure that 250 certificates will be deposited. Even though you will not use the certificate yourself, your obtaining it will assist others to save railroad fare.

The general committee in charge of the convention is as follows: Messrs. B. D. Hull (Chairman), Edward Bennett, H. E. Bussey, J. M. Chandlee, H. W. Eales, J. Harrison, Chris. H. Kraft, L. W. W. Morrow, C. P. Potter, W. L. Rose, Herbert S. Sands. A very complete organization of subcommittees has been carrying out the details of the plans. The chairmen of the subcommittees are: Entertainment, W. L. Rose; Finance, G. A. Waters; Publicity, C. L. Matthews; Registration and Hotel, J. M. Chandlee; Special Feature, C. H. Kraft; Technical Inspection, C. C. Robinson; Technical Meetings, C. P. Potter, and Transportation, J. L. Buchanan.

A. I. E. E. Annual Business Meeting

NEW YORK, MAY 15, 1925

The annual business meeting of the A. I. E. E., will be held on Friday, May 15, at 8:15 p. m. in the auditorium of the Engineering Societies Building, 33 West 39th Street, New York City. At this meeting the results of the annual election of Institute officers will be announced and the report of the Board of Directors for the year ending April 30 will be presented.

Following the business session an address on a subject of timely interest will be made by a speaker of national prominence. This feature of the evening's program will be conducted under the auspices of the New York Section.

The Annual Convention at Saratoga Springs

A number of very pleasant and attractive features will be offered by the coming Annual Convention which will be held in Saratoga Springs, N. Y., June 23-27. The social and sports activities will take a large share of the program as is customary at the Annual Convention. Also much valuable technical ma-

terial will be presented and probably two evening meetings will be held on topics of wide and live interest. This convention will furthermore be the occasion for an all-day conference of Section delegates.

Saratoga Springs, located in the Adirondack Mountains, abounds in opportunities for outdoor enjoyment. Every afternoon of the convention will be free to spend in sports or other recreation. Lovers of golf will enjoy the excellent courses which are located there. Tennis players likewise will find good courts nearby. Beautiful automobile drives lie in all directions and many of the visitors will take their own cars to the convention.

There will be dances probably on two evenings and several enjoyable entertainment features. The President's reception will be held Tuesday evening. The ladies will find much to enjoy in this meeting. Complete arrangements will be made for their pleasure and numbers of them will attend.

The Technical Program

Reviews of the progress in the various technical fields will be presented by the respective Technical Committees during Tuesday and Wednesday of the convention week. A number of picked technical papers on live subjects will be scheduled for Thursday and Friday.

Two special evening meetings are planned at which prominent speakers will give addresses. The subjects contemplated for these meetings are railroad electrification and engineering education.

The conference of the Section delegates will be held all day Monday. At this conference the accomplishments, plans and problems of the Institute Sections will be discussed. All members of the Institute are invited to be present at this conference and to join in the very interesting discussion which will take place.

A specially attractive event of the meeting will be a trip to the works of the General Electric Company at Schenectady. This trip will be made probably Wednesday afternoon.

The appointment of the convention committee will soon be completed and active work on the details will be pushed forward. The chairman of the committee is James R. Craighead, Assistant Engineer, General Engineering Laboratory, General Electric Company, Schenectady.

Pacific Coast Convention to be Held in Seattle, September 15th

This year the Pacific Coast Convention is going to be held in Seattle, commencing September 15 and continuing several days.

As yet no definite plans can be announced but the convention committee is being organized and will soon have plans under way. G. E. Quinan, chief electrical engineer, Puget Sound Power and Light Company, has been appointed chairman of the committee.

Regional Meeting at Swampscott has High Quality Program

A very comprehensive program is planned for the second Regional Meeting of the Northeastern District of the Institute which will be held at Swampscott, Mass., May 7, 8 and 9. This meeting follows up the successful meeting held by the District at Worcester, Mass., last year which was the pioneer meeting of its kind. At the coming meeting the Lynn Section will be host.

The New Ocean House in which the meeting will be held is charmingly situated by the ocean shore. On the hotel grounds is a nine-hole golf course, a putting green and several good tennis courts. There is also excellent boating and fishing and a fine bath house, although at the time of the Convention the water will be rather cold.

A program for the Convention is being arranged that will combine recreation and entertainment with the more serious work of the technical sessions. The social side of the program is under the direction of a committee from the Lynn Section, recruited from those who did so much toward making the non-technical features of the National Convention in 1923 a success. The arrangements include a banquet and evening entertainment, also golf, tennis, auto trips to nearby points of interest and a fishing trip on Saturday to Egg Rock.

Dr. Elihu Thomson has been scheduled as the speaker at one ol the evening meetings and this will be an occasion which wilf be enjoyed by a large attendance.

As for the technical sessions, there will be papers on such subjects as Transmission Problems, High-Voltage Power Cable, Tap Changing Under Load, Electrical Measurements, and Engineering and Industrial Education. Many of these papers are by nationally known engineers, presenting material of great interest and importance to the profession. Others will be presented by younger authors in competition for Regional and National "first-paper" prizes.

The plan so successfully carried out at the Worcester Convention last year, of having plenty of time available for detailed discussion of the important papers, will be followed again this year. With this in mind it is planned to have many of the "first papers" presented in abstract. This procedure will in no way interfere with their value as it is expected that such papers will be printed for distribution previous to the meeting. Among these are several "first papers" which have been scheduled for past or future national conventions. These are placed on the program to make them eligible for the prizes and will be presented by title only.

The meeting is being arranged under the guidance of the Coordinating Committee of the District formed for the purpose. This Committee consists of H. B. Smith, Vice-President of the Northeastern District, who is Chairman, A. C. Stevens, Secretary, F. T. Byrne, J. R. Craighead, F. S. Jones, A. E. Knowlton and B. W. St. Clair. The local arrangements are being handled by the local convention committee which is as follows: B. W. St. Clair, Chairman, F. H. Bowman and F. S. Jones.

Tentative List of Papers for Swampscott Meeting

Overvoltages on Transmission Systems Due to Dropping of Load, E. J. Burnham, General Electric Co.

Sleet and Ice on Transmission Lines, C. R. Oliver, New England Power Co.

Electro-Mechanical Problem Analyzer, C. A. Nickle, General Electric Co.

Transmission Paper or Discussion, N. G. Reinicker, Pennsylvania Power & Light Co.

Tap Changing Under Load, H. C. Albrecht, Philadelphia Electric Co.

Voltage Control Obtained by Varying Transformer Ratio, L. F. Blume, General Electric Co.

Changing Transformer Ratios without Interrupting the Load, M. H. Bates, General Electrical Co.

Universal-Type Motors, L. C. Packer, Westinghouse Electric & Mfg. Co.

A Two-Speed Salient-Pole Synchronous Motor, R. W. Wieseman, General Electric Co.

Short-Circuit Currents of Synchronous Machines, R. F. Franklin, General Electric Co.

Losses in Iron Under the Action of Superposed A-C. and D-C. Excitation, J. E. Jackson, Alabama Power Co. and O. E. Charlton, General Electric Co.

Oil-Filled Terminals for High-Voltage Cables, E. D. Eby, General Electric Co.

Investigation of High-Voltage Cable Joints, E. W. Davis and G. J. Crowdes, Simplex Wire & Cable Co.

Cooperative Course in Electrical Engineering, Professor W. H. Timbie, Massachusetts Institute of Technology

Education in Industry, S. W. Ashe, General Electric Co.

Calibration of Wave Meters, Jas. K. Clapp, Massachusetts Institute of Technology

Predetermination of Self-Cooled Oil-Immersed Transformer Temperatures, W. H. Cooney, General Electric Co.

Study of Time Lag of the Needle Gap, K. B. McEachron and E. J. Wade, General Electric Co.

Recent Improvement in A-C. Indicating Instruments, S. H. Hoare, General Electric Co.

Measurement of Electrical Output of Large A-C. Turbo-Generators, E. S. Lee, General Electric Co.

Temperature Errors in Induction Watthour Meters, I. F. Kinnard and H. T. Faus, General Electric Co.

Effect of Repeated Voltage Application on Fibrous Insulation, F. M. Clark, General Electric Co.

Board of Directors to Meet in St. Louis April 14

A meeting of the Board of Directors will be held in St. Louis, Mo., during the Spring Convention. The meeting will be held at the Hotel Chase which is Convention headquarters at 4:30 P. M., Tuesday, April 14, 1925.

A. I. E. E. Directors' Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, March 13, 1925.

There were present: President Farley Osgood, Newark, N. J.; Vice-Presidents William F. James, Philadelphia; Harold B. Smith, Worcester, Mass.; L. F. Morehouse, New York; Managers R. B. Williamson, Milwaukee; G. L. Knight, Brooklyn, N. Y.; H. P. Charlesworth, New York; E. B. Merriam, Schenectady, N. Y.; Treasurer George A. Hamilton, Elizabeth, N. J.; Secretary F. L. Hutchinson, New York.

Chairman L. W. W. Morrow of the Meetings and Papers Committee appeared before the Board and reported orally upon the plans of the committee regarding the Annual Convention and other meetings of the Institute.

The Board ratified the approval of the Finance Committee of monthly bills amounting to $24,389.18.

A report of the meeting of the Board of Examiners held March 9, was presented and the actions taken at that meeting were approved. Upon the recommendation of the Board of Examiners, the following actions were taken: 150 Students were ordered enrolled; 343 applicants were elected to the grade of Associate; 11 applicants were elected to the grade of Member; 6 applicants were transferred to the grade of Member; 1 applicant was transferred to the grade of Fellow.

An application for authority to organize a Student Branch of the Institute at the Missouri School of Mines and Metallurgy, Rolla, Mo., was considered and the Board voted to authorize the establishment of this Branch.

Upon the recommendation of the Standards Committee, the Board voted to adopt a report of Working Committee No. 27, outlining the "General Principles upon which Temperature Limits are Based in the Rating of Electrical Machinery and Apparatus," to be printed and made available in pamphlet form in connection with the general revision of the Standards.

Dr. John B. Whitehead, Chairman of the Institute's Committee on Research, was nominated, for appointment by the National Academy of Science, as a representative of the Institute on the Engineering Division of the National Research Council, to succeed Mr. Bancroft Gherardi, whose term expires June 30, 1925.

The report of the Committee of Tellers on the nomination ballots received for the offices to be filled at the coming annual Institute election, was presented and the Board selected the "Directors' Nominees" as indicated elsewhere in this issue.

The Board voted to request the Constitutional Revision Committee to act as a Special Committee on Revision of the By-laws of the Institute, to formulate for action by the Board of Directors such additions or amendments to the by-laws as may be necessary in case the amendments to the constitution now being voted upon are adopted; also to consider and make recommendations upon any other changes in the by-laws as may be originated in the committee or received from any member of the Institute.

A communication from Executive Secretary L. W. Wallace of American Engineering Council was read, transmitting the following resolution adopted by representatives of local member societies in conference immediately following the January meeting of the Assembly of American Engineering Council:

"Voted: This group of representatives on the Assembly of American Engineering Council, coming from the local engineering societies, requests the Executive Secretary to express to the American Society of Mechanical Engineers and the American Institute of Electrical Engineers the deep appreciation of the local engineering societies of the support to the engineering profession given by these two societies in remaining the backbone of American Engineering Council."

Others matters of importance were discussed, reference to which may be found in this and future issues of the Journal.

Future Section Meetings

Baltimore

Power from Waste Fuel, by Messrs. Coulter and Schnure, Bethlehem Steel Co. April 17, 8:15 P. M., Sparrows Point, Md.

European Practise, by W. B. Potter, General Electric Co., May 15, 8:15 P. M.

Erie

Automatic Substations, April 21.

The Telephone. May 19.

Fort Wayne

Inspection trip to the new automatic telephone exchange, corner Barr and Berry Streets. Mr. E. L. Gaines will have charge of the meeting. April 23, 8:00 P. M.

Annual Banquet. May 21.

New York

A meeting of the New York Section of the A. I. E. E. will be held in the auditorium of the Public Service Building, Newark, N. J. on the evening of Tuesday, April 21, 1925. Details as to speakers, etc., will be announced at a later date.

St. Louis

National Spring Convention. April 13-17.

Super-Power Systems. May 27.

Seattle

Economies of Transmission-Line Design, by E. A. Loew. April 15, Tacoma.

Baker River Development, by L. N. Robinson. Election of Officers. May 20.

Vancouver

Hydro-Electric Developments of the East Kootenay Power Company, by M. L. Wade. May 1.

A. I. E. E. Annual Election

At the meeting of the Board of Directors of the Institute held in New York, March 13, the report of the Committee of Tellers, giving the result of its canvass of the nomination ballots received for the offices to be filled at the coming annual election, was presented.

This report included the names of all candidates eligible for election, the names of those who received less than three per cent of the total nomination vote having been eliminated in accordance with the requirements of the constitution.

The Board selected the following list of "Directors' Nominees" for the offices to be filled:

For President: Dr. Michael I. Pupin, New York, N. Y.
For Vice-Presidents: District No. 2 (Middle Eastern)
Arthur G. Pierce, Cleveland, Ohio
District No. 4 (Southern)
W. E. Mitchell, Birmingham, Ala.
District No. 6 (North Central)
Herbert S. Sands, Denver, Colo.
District No. 8 (Pacific)
P. M. Downing, San Francisco, Calif.
District No. 10 (Canada)
W. P. Dobson, Toronto, Ont.
For Managers: M. M. Fowler, Chicago, Ill.
E. C. Stone, Pittsburgh, Pa.
H. A. Kidder, New York, N. Y.
For Treasurer: George A. Hamilton, Elizabeth, N. J.

The election ballots were mailed to the entire membership prior to April 1, in accordance with the constitution.

The report of the Committee of Tellers follows:

REPORT OF COMMITTEE OF TELLERS ON NOMINATION BALLOTS

March 6, 1925

To the Board of Directors,
American Institute of Electrical Engineers

Gentlemen:

This Committee has counted and canvassed, in accordance with Article VI of the Constitution, the nomination ballots received for officers of the Institute for 1925-1926. The result is as follows:

Total number of envelopes said to contain ballots received from the Secretary		2638
Rejected on account of bearing no identifying name on outer envelope	35	
Rejected on account of having reached Secretary's office after February 28	78	113
Leaving as valid ballots		2525

These valid ballots were counted and the result is shown below:

FOR PRESIDENT

Michael I. Pupin	2440
Scattering and blank	85
Total	2525

The scattering vote was divided among 11 candidates, each of whom received less than three per cent of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices.)

FOR VICE-PRESIDENTS

District		
No. 2. Middle Eastern	Arthur G. Pierce	1748
	T. H. Schoepf	423
	Scattering and blank	354
No. 4. Southern	W. E. Mitchell	2107
	Scattering and blank	418
No. 6. North Central	H. S. Sands	2158
	Scattering and blank	367
No. 8. Pacific	P. M. Downing	2136
	Scattering and blank	389
No. 10. Canada	W. P. Dobson	2120
	Scattering and blank	405

(The scattering vote was divided among 22 candidates, each of whom received less than three per cent of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices).

FOR MANAGERS

M. M. Fowler	1731
E. C. Stone	1592
H. H. Kidder	1518
Ross B. Mateer	1105
E. B. Meyer	963
Scattering and blank	666

(The scattering vote was divided among 31 candidates, each of whom received less than three per cent of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices).

FOR TREASURER

George A. Hamilton	2156
Scattering and blank	369
Total	2525

(The scattering vote was divided among 7 candidates, each of whom received less than three per cent of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices).

Respectfully submitted,
R. R. Kime, *Chairman*
W. G. Freeman
E. A. Merwin
J. W. Nostrand
A. F. Hamdi
Committee of Tellers

New York Electrical Society to Visit Edison Lamp Works

On the evening of April 16, 1925 the New York Electrical Society will make a visit to the Edison Lamp Works of the G. E. Co. at Harrison, N. J. A buffet supper will be served at 6 p. m. Directly after supper a talk will be given by George H. Stickney, Illuminationg Engr. of the Works on "Lighting Education by the Visual Method." An inspection of the lighting exhibit will follow. This exhibit includes every modern type of lighting equipment, covering home, office, store, show window, factory, street, auto, sign, flood lighting, etc.

Third Hydroelectric Conference Held by Engineers Club of Philadelphia

The third annual Hydroelectric Conference under the auspices of the Engineers Club of Philadelphia was held on March 10. Seven technical papers dealing with the general topic of "Practical Problems of Operation" were presented by eminent engineer in morning and afternoon sessions and a dinner held in the evening in the Bellevue-Stratford Hotel was followed by addresses by three prominent speakers.

The morning session dealt particularly with the operation of hydraulic machinery employed in generating plants. The first paper was *The Operation of Hydroelectric Systems with Auxiliary Steam Plants for Best Economy and Proper Governing*, by W. M. White, Allis-Chalmers Manufacturing Company. This was followed by *Operation of Hydroelectric Units for Maximum Kilowatt Hours*, by F. Nagler, Allis-Chalmers Manufacturing Company. Next on the program was a paper *Inter-Relation of Operation and Design of Hydraulic Turbines*, by F. H. Rogers and L. F. Moody, of the William Cramp & Sons Ship and Engine Building Company. Then E. C. Hutchinson of the Pelton Water Wheel Company presented *Operating Problems and Their Relation to the Design of Hydroelectric Machinery in the West.*

The afternoon session was devoted to the electrical equipment of hydroelectric plants and opened with the paper *Operating Practise in Hydroelectric Developments*, by C. B. Hawley, Consult-

ing Engineer. This was followed by *Features of Design in Latest Large Hydroelectric Generators*, by M. C. Olson, General Electric Company. F. D. Newbury, Westinghouse Electric & Mfg. Co., presented the last paper of the session, *Recent Developments in Hydroelectric Generators.* Much pertinent and valuable discussion was offered by a number of engineers at both technical sessions.

The addresses in the evening were on broad topics relating to water power development. The first speaker was Dr. W. F. Durand, President of the American Society of Mechanical Engineers and the subject of his talk was *Power and Its Relation to American Progress.* Charles Penrose of Day and Zimmerman, Inc., was the second speaker and his topic was *Power in Pennsylvania.* The closing address of the evening was given by A. E. Pope of the New England Power Company who spoke on *Water Power's and Superpower's Contributions to New England.*

Student Convention in Philadelphia is Very Successful

An innovation for the Institute, a Student Branch convention, was held on March 9 at the Moore School of Electrical Engineering, University of Pennsylvania, under the direction of the Philadelphia Section. Students from nine colleges and others attended the meeting making a registration of about 300. The meeting lasted one day and consisted of technical papers by students in the morning, inspection trips in the afternoon and a dinner and an address by President Farley Osgood in the evening.

This meeting was entirely worth while to the students and to the Institute. It increased the students' interest in A. I. E. E. affairs and gave them an excellent opportunity to meet the electrical students from the other colleges. Those responsible for the arrangements deserve high commendation.

The technical session consisted of the following papers.

The Small College in Engineering Education, by John B. Donal, Swarthmore College.

A Voltage Survey, by F. J. Berger, Lehigh University.

Radio Broadcasting at Haverford College, by Winthrop M. Leeds and Gerald C. Gross, both of Haverford College.

The Oil-Electric Locomotive, by J. B. Powell and C. L. Craven, both of Lafayette College.

Three inspection trips were made in the afternoon. These were to (1) Delaware Station of the Philadelphia Electric Company, (2) Parkway Building of the Bell Telephone Company of Pennsylvania and (3) Villa Nova, Haverford and Swarthmore Colleges.

After the dinner in the evening President Farley Osgood spoke on "What a College Man Goes Up Against and How to Meet it." He gave a very inspiring talk outlining some of the problems which the engineering graduate has to face and giving some very wholesome practical advice on overcoming these problems.

The colleges participating in the convention were Drexel Institute, Haverford College, Lafayette College, Lehigh University, Princeton University, Swarthmore College, University of Delaware, University of Pennsylvania and Villa Nova College. Special credit for planning and conducting the meeting must be given to the officers of the Philadelphia Section, the officers of the Student Branch at Moore School of Engineering and the Student Branch Activities Committee, consisting of professors and other engineers in the territory represented.

Commission of Washington Award Endowment Increased

The Commission of Washington Award endowment has just been increased by the amount of $2000. This increase in the fund is made by its founder John W. Alvord, Past President of the Western Society of Engineers in order that the annual expenses incurred in connection with the award may be properly provided for and that the presentation may not be hampered in any way.

The Commission of Washington Award was established in 1917 "to be annually presented to an engineer whose work in some special instance, or whose services in general have been noteworthy for their merit in promoting the public good." The award is made annually be a committee composed of nine representatives of the Western Society of Engineers and two each from the A. S. C. E., the A. I. M. E., the A. S. M. E. and the A. I. E. E. Three awards have been made, as follows: Herbert Hoover, 1919; Captain Robert W. Hunt, 1922; Professor Arthur N. Talbot, 1924.

American Institute Arranges Exposition of Inventions

During the week of April 27th to May second, inclusive, The American Institute of the City of New York, now in the 97th year of its service to American Industry, is planning to hold an exhibition which will tell the "story of invention from the dawn of civilization to the 'day after tomorrow.'" This will be held at the Engineering Societies Building, 33 West 39th Street, and able inventors, research engineers, chemists, as well as those who have had much to do with the development of inventions, will unite in telling the chapters of this marvelous progress.

Among the speakers on the program, more than fifty in all,—are Doctor Ira N. Hollis, President of Worcester Polytechnic Institute; Dexter S. Kimball, Dean of the College of Engineering Cornell University; Professor Joseph W. Roe, New York University; C. M. Keys, of the Curtiss Aeroplane & Motor Company; Doctor Alfred B. Hitchins, of the Duplex Motion Pictures; Lieutenant-Commander George E. Brandt, Secretary General of the Conference on Oceanography; Stephen H. Horgan, Inventor of the half-tone.

Insulator Test Specifications

Through oversight, the last section of "Insulator Test Specifications" was omitted as published in the March JOURNAL, page 300. The omitted part follows:

IX. OPTIONAL TESTS—SUSPENSION INSULATORS

1. *Thermal Test.* After the routine "Test after Assembly" a number of representative assembled insulators shall be subjected to a "Thermal Test." Specifications for this test shall be the same as the specifications for the "Thermal Test" on pin insulator shells, except that the word "unit" shall be substituted for the word "shell."

Society of Automotive Engineers on Storage Batteries

Although the recent Storage Battery Division recommendations was approved by the voting members of the S. A. E., criticisms of the report were submitted by Mr. T. L. Lee and R. G. Thompson, both being of the opinion that the sizes adopted are too small and not in conformity with standards recently adopted by the Automotive Electric Association. It is recommended that further investigation be made, working toward the adoption of the same storage battery standards for both the S. A. E. and the A. E. A.

National Directory to be Ready Soon

According to announcement received from the Bureau of Standards, Department of Commerce, a new directory of commodity specifications is now in the Government Printing Office, and it is expected that it will be ready for distribution very shortly. It is to be followed by an Encyclopedia of Specifications, giving loose pamphlet copies of important specifications, especially those which are not readily obtainable elsewhere. 6000 commodities will be included, in a volume of approximately 600 pages, purchasable at a price of about $2.00.

Fellowship With Engineering Council of Utah

The Engineering Council of Utah, with headquarters at Salt Lake City, has completed arrangements whereby regularly organized luncheon gatherings will be held every Monday at the Salt Lake Chamber of Commerce, at 12:15 p. m. The Council extend a cordials invitation to all visiting engineers to attend these luncheons, and would greatly appreciate notice of such expected visits in advance if possible. Notification may be sent to any local engineer, to Mr. H. W. Clarke, President of the University of Utah, and Chairman of the Utah Section of the Institute, or to Mr. John Solberg, Secretary, in care of the Interurban Station.

Changes in Electrical Safety Code

Changes to be incorporated in the new edition of the National Electric Safety Code, as approved at a meeting of the Sectional Committee dealing with the code, held at the Bureau of Standards March 5-6, 1925, will include rules for the construction of radio antennas, the prohibition of grounded returns on power circuits in cities and changes in the loading map. It is one of the provisions of the American Engineering Standard Committee, under whose jurisdiction this Code comes, that it shall be revised periodically every few years, in order that it shall embody the most modern practises.

A working table for stresses in steel structural supports has also been established.

American Engineering Standards Committee

AN ECONOMIC BASIS FOR SIZES

A system by which basic sizes, or "preferred numbers" of commodities may be established is being investigated and developed by a special committee recently appointed by the A. E. S. C. It will be the work of this Committee to study the possibilities of size-series, enlisting the interest of the engineers of industrial Europe, particularly in the mechanical and electrical engineering fields, toward an able completion of this undertaking.

AMERICAN ENGINEERING COUNCIL

UNCLE SAM'S BIGGEST MAP 6000 SHEETS

After forty-five years of intermittent effort, the work on this map is being rushed to completion and in less than a generation, the United States will have completed atlas of its entire territory. Honorable James Hartness declares that the passing of the Temple Bill by President Coolidge is of enormous social and industrial significance to the nation, since it greatly facilitates and accelerates the work of the U. S. Geological Survey and the precise triangulation and leveling of the U. S. Coast and Geodetic Survey, the organizations who are doing this work.

The map will cost $50,000,000, and will show not only every railroad, bridge, house, etc., but every natural feature as well. It is the result of an exact physical survey of every square mile, —indeed every acre,—of the area to be mapped.

PERSONAL MENTION

Chester J. Haines has accepted a position in the engineering department of the Edison Company at Easton, Pa.

Sylvan Harris has removed from Philadelphia to join the Radio News, Experimenter Publishing Co., Inc., New York City.

Carl H. Hermance is now with the California State Railroad Commission as Assistant Engineer, with offices at San Francisco, California.

Allen McLean, previously with the American Telephone and Telegraph Company at Philadelphia, has joined the Sleeper Radio Corporation, Long Island City, New York.

W. O. Powers, who was previously with the Thos. E. Murray, Inc., has entered the Engineering Department of the Postal Telegraph-Cable Company, New York City.

Walter H. Sammis has recently transferred his activities from C. H. Tenney and Company, Boston, to the Consumers Power Company, Jackson, Michigan.

E. W. Trafford has left the Department of Public Utilities, Richmond, Va., and has established his own offices there as consulting engineer.

E. H. Ryden, formerly electrical engineer for the Western Electric Company is now with the Electrical Engineering Department of the Utica Gas and Electric Company, Utica, New York.

Philip C. Bangs, who has been doing electrical and radio engineering work for some time past at Atlanta, Ga., has identified himself with Messrs. Warren Webster & Company, Spartanburg, S. C., where he will be located.

William E. Hooper has made new affiliations with the C. B. Roberts Engineering Company, Bethlehem, Pa., having severed his connections with the Bangor Railway and Electric Company Bangor, Maine.

J. Arthur Ramsay, Electrical foreman for the New Cornelia Copper Company, Casa Grande, Arizona, has made new connections with the Superior and Boston Copper Company, Copper Hill, Arizona.

William C. Rudd, Consulting Engineer at Cincinnati, Ohio, has accepted an appointment as Assistant Engineer in the Power Department of Water Supply for the City of Detroit, in which city he will now be located.

C. A. Patterson, who has been at Guanajuato, Gto, Mexico, with the Central Mexico Light and Power Company for the past year or more, has returned to the United States to relocate with the Alabama Power Company, Birmingham, Alabama.

A. L. Van Emden recently severed his connections with the Engineering Department of the Boston Elevated Railway to establih new affiliations with the East Pittsburgh works of the Westinghouse Electric and Mfg. Company, as a Railway Control engineer.

W. W. Simons has resigned from the service of the Telephone Supply Sales Department of the Western Electric Company and has taken up new activities in the Engineering Department of the David Grimes Radio & Cameo Record Corporation, Jersey City, N. J.

G. E. Sanderson, who, for the past few years, has been Sales Engineer for the Westinghouse Electric & Manufacturing Company, Syracuse, N. Y., has been made District Manager for the Wagner Electric Corporation, his special district covering northern, central and western New York.

A. G. Paulsen has been transferred to Caracas, Venezuela, from Merida, Yucatan, where, for the past six years, he has served first in the capacity of Chief Engineer and, since 1920, as General Manager of the Compania de Electricidad de Merida. He is now with the Venezuela Electric Light Company, Ltd., which is also a subsidiary of the International Light & Power Company, Ltd., of Toronto, Canada.

Lewis M. Clement, for the past nine years in charge of the radio receiver and special development work for the Western Electric Company and now of the new Bell Telephone Laboratories, Inc., has joined the Engineering Staff of the F. A. D. Andrea, Inc., New York City. Since his graduation from the

University of California in 1914, Mr. Clement's experience in the electrical field has been varied and noteworthy.

Ralph H. Tapscott, who for six years has been Assistant Chief Electrical Engineer of the New York Edison Company, has been made Electrical Engineer there. For seven years after graduation from Union College, Mr. Tapscott was with the General Electric Company of Schenectady in their Lighting Engineering Department, following one year in the Testing Department. He is a member of the N. E. L. A. as well as of the Institute, and has many times served officially on Committees of both organizations.

W. Nelson Smith, Consulting Electrical Engineer of the Winnipeg Electric Company, has returned to Winnipeg after a year's leave of absence spent in Vancouver, B. C., where he assisted the Sydney E. Junkins Company, B. C., Ltd., in preparing a report on the electrification of the mountain district of the Canadian Pacific Railway. Mr. Smith's experience in steam railway electrification reaches back over a period of more than twenty years. He is now engaged in the valuation of an extensive light and power distribution system for the Winnipeg Electric Company.

Obituary

Hervy F. Mitchell, while working on a switchboard in the O Street substation, Fresno, California, came in contact with a high voltage switch causing an arc that shocked and burned him causing death. Born in Pasadena, November 2, 1896, Mr. Mitchell's early education, after high school, was a year in Junior College followed by a year in the California Institute of Technology. He began work with the San Joaquin Power Company while a boy of fifteen, subsequently taking a course in electricity at Throop Polytechnic School. From Los Angeles, in 1918, he enlisted in the seventh provisional company, Ordinance Corps, as an electrician. Serving at Camp Hancock, Ga., on January 18, 1919, he was given honorable discharge and returned to the San Joaquin Valley and the San Joaquin Power, by whom he was considered one of the most promising young men in the organization. Mr. Mitchell joined the Institute, August 2, 1923.

Gordon Cameron, after an extended illness of eleven months, died at the Good Samaritan Hospital, Los Angeles, March 10th, 1925. Mr. Cameron was born at Hamilton, Canada, October 1st, 1884. His education was through the Ontario Grade and High Schools and the Collegiate Institute of Hamilton. In 1912 he was graduated, with the degree of B. Sc. in Electrical Engineering from the Queen's University, Kingston, Ont., prior to that time having spent one summer in the Test Dept. of the Canadian Westinghouse Co. and in service as inspector on High Tension Line Construction for the Hydro Electric Power Commission of Ontario. He was with the Canadian Westinghouse Company from 1912 to 1915, as engineer and designer of Switching Equipment; in 1915-16 he taught in the Hamilton Technical School, but in 1916 returned to the commercial field as engineer of the Oil Circuit Division of the Condit Electric Mfg. Co., South Boston, Mass. During the World War, Mr. Cameron served as Chief Electrical Engineer in the Quartermaster Corps, War Dept., Washington, D. C., from which service he joined the Western Machinery Company, Los Angeles, in 1923, remaining with them up to the time of his death.

William Walter Bradfield, Manager of the Marconi Wireless Telegraph Company, died in London, March 18th, 1925. Born in London, 1879, Mr. Bradfield graduated from a finishing Technical College in 1896 and immediately commenced his work with the Marconi Company, working as assistant to William Marconi in the early days of commercial radio work. He was one of those to take active part in the first installations of wireless apparatus on board British and American battleships. At the time of his death, Mr. Bradfield was Director and Joint Manager of the Marconi's Wireless Telegraph Co., Ltd., Marconi House, London.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES (MARCH 1-31 1925)

Alternating Current Rectification

By L. B. W. Jolley. N. Y., John Wiley & Sons, 1924. 352 pp., illus., diagrs., tables, 9 x 6 in., cloth. $5.00.

The use of unidirectional currents has a very large application both in the supply of power and in the laboratory, and it is the purpose of this book to describe the methods available for their production, and to present the mathematical analysis with numerous examples where possible. The author covers a wide field, comprising voltages from one hundred thousand volts down to a fraction of a volt, and includes consideration of many methods of rectification. Numerous bibliographies are included.

Annuaire Pour L'An 1925.

By France. Bureau des Longitudes. Paris, Gauthier-Villars et Cie., 1925. [884] pp., tables, 6 x 4 in., paper. 6 fr. .50.

In addition to the customary data respecting the calendar, geodesy, astronomy, weights and measures, geography, population, etc., this almanac for 1925 contains a paper on the influence of the rotation of the earth on the physiognomy of the tides, by E. Fichot, and one on the applications of the three-electrode vacuum tube to astronomy, by G. Ferrié.

Carburants Nationaux, Exposition de Buc-Congrès; Compte Rendu des Travaux du Comité Central de Culture Mécanique en 1924. Paris, Chaleur et Industrie. 264 pp., 9 x 6 in., paper. 15 fr.

As a supplement to its December, 1924 issue, "Chaleur et Industrie" publishes the proceedings of the Congrès des Carburants held in Paris, in October 1924, under the auspices of the Ministry of Agriculture. The specific problem that occupied the attention of the Congress was the transformation of mineral and vegetable substances of French origin into fuels for internal combustion engines.

Among the subjects discussed were the Berthelot process of hydrogenation, the Bergius process of liquid fuel production, the manufacture of synthetic petroleum from vegetable and animal oils, the theory underlying synthetic motor fuels, the alcohol engine, the production of motor fuel by the carbonization of solid fuels, the use of vegetable oils, producer-gas trucks and farm tractors, colloidal fuels and the use of power in farming.

Chart Showing the Chemical Relationships in the Mineral Kingdom.

By Palmer Cosslett Putnam. N. Y., John Wiley & Sons, 1925. 31 pp., chart, 10 x 7 in., fabrikoid. $3.00.

The author has tabulated the chemical constituents of all minerals described in literature before July, 1924—some 1611 in all—in such a manner as to make clear the chemical relationships that exist. The chart answers quickly such practical questions as "How many and what are the minerals that contain germanium, and what are their compositions?"; or "Does silver occur with oxygen in any mineral?"; or "Do phosphides or silicides occur as minerals?" It also will serve as an aid in determinative mineralogy, especially in the case of rare minerals, where the small amount of the unknown materials precludes the possibility of many tests.

Charts and Graphs.

By Karl G. Karsten. N. Y., Prentice-Hall, Inc., 1923. 724 pp., illus., diagrs., charts, 9 x 6 in., fabrikoid. $6.00.

A comprehensive text on the theory and use of charts of all kinds, with instructions for making them. The author adopts a theory of the evolution of charts, in accordance with which all forms fall into line with simple origins and clear channels of growth, and his text follows this evolution, proceeding from simple, non-mathematical forms to complicated ones. The proper uses of each form and the purposes to which it is suited are discussed thoroughly.

Chemistry in the Service of Man.

By Alexander Findlay. 3rd edition. Lond. & N. Y., Longmans, Green & Co., 1925. 300 pp., illus., ports., 8 x 5 in., cloth. $2.00.

Intended to give readers without chemical knowledge, a readable, intelligible account of some of the more important general principles and theories of chemical science and of their applications. The author hopes that it may give the general reader some idea of his indebtedness to the chemist and also stimulate the interest of young students of chemistry.

Three new chapters have been added to this edition, and various portions revised and rewritten.

Crystals and the Fine-Structure of Matter.

By Friedrich Rinne. N. Y., E. P. Dutton & Co., n. d. 195 pp., diagrs., plates, ports., 9 x 6 in., cloth. $4.20.

In 1921 Dr. Rinne published a book which considered experiments on the fine-structure of matter from a new and essentially crystallographic point of view. The interest shown in this publication led to the preparation of the present greatly enlarged edition.

The author has endeavored to deduce the main characteristics of the fine-structural constitution of matter from the properties of crystals and to present his ideas in a form which will not only be informing to fellow-students but will also be comprehensible to general readers.

Electrical Measuring Instruments, pt. 2; Induction Instruments, Supply Meters and Auxiliary Apparatus.

By C. V. Drysdale and A. C. Jolley. Lond., Ernest Benn, Ltd., 1924. 475 pp., illus., diagrs., tables, 10 x 7 in., cloth. 55 s.

Like the previous volume of this work, this book is written with the needs of the designer and constructor of instruments in mind and is intended to do for him what books on dynamo design do for the electrical engineer. It also supplies detailed information on the construction and performance of the various types of instruments which is wanted by users.

Volume two treats of supply meters, induction meters, frequency meters, phase meters, devices for extending the range of a-c. instruments, electrical devices for mechanical testing (tachometers, brakes and dynamometers), and some special indicating instruments. There is a chapter on test-room equipment. The book deals primarily with instruments for commercial use.

Electrolytic Rectifier.

By N. A. de Bruyne. Lond. & N. Y., Isaac Pitman & Sons, 1924. 75 pp., illus., diagrs., 7 x 5 in., cloth. $1.00.

This little book, which the author states to be the first on the electrolytic rectifier, is intended especially for amateurs. The characteristics of these rectifiers are described, the theory explained and the principal uses noted. Directions are given for making a simple rectifier which can be used to charge the accumulators of radio receiving sets.

Elektrochemie........v. 1; Allgemeine Elektrochemie.

By Heinrich Danneel. Ber. u. Lpz., Walter de Gruyter & Co., 1924. 173 pp., diagrs., 6 x 4 in., cloth. 1.25 rm.

The first of two small volumes planned to present, with the greatest conciseness, the elements of electrochemistry. This volume treats of the fundamental physical and chemical phenomena, discussing such basic topics as work, chemical mechanics, the theories of dissociation and solution conductivity, electromotive force, polarization, electrolysis and electrons.

Elements of Colloidal Chemistry.

By Herbert Freundlich. N. Y., E. P. Dutton & Co., [1924]. 210 pp., diagrs., 8 x 5 in., cloth. $3.00.

A strictly non-mathematical introduction to the subject of colloids, intended for students of medicine and technical chemistry. It deals fully with fundamental principles, including capillary chemistry, the rate of phase formation and the Brownian movement; and also discusses sols, gels, mists, smokes, foams, etc.

Examples in Battery Engineering.

By F. E. Austin. Hanover, N. H., The author, 1917. 90 pp., illus., diagrs., 8 x 5 in., cloth. $1.25.

This textbook considers those matters that are important in the efficient operation of electric cells and batteries of all types. The fundamental principles are set forth and their application illustrated by examples which are solved in detail.

Funfundzwanzig Jahre Zeppelin-Luftschiffbau.

By L. Dürr. Berlin, V. D. I. Verlag, 1925. 83 pp., illus., diagrs., 12 x 9 in., paper. 8 g. m.

The completion of the "Los Angeles" marked the end of twenty-five years activity for Zeppelin factory, an occasion that the company has commemorated by the present volume. The book contains a detailed description of the "Los Angeles" and also interesting accounts of the progressive changes in the design of the Zeppelin and of its structural parts which have occurred during these twenty-five years. These have much historic interest as a record of the way in which a practicable airship has been evolved.

Illuminating Engineering; Prepared by a Staff of Specialists.

Edited by Francis E. Cady and Henry B. Dates. N. Y., John Wiley & Sons, 1925. 486 pp., illus., diagrs., plates, tables, 9 x 6 in., cloth. $5.00.

This textbook is an outgrowth of a course in the subject which has been given for six years at the Case School of Applied Science by a number of specialists in various branches of illumination, most of whom are connected with the National Lamp Works of the General Electric Company or the Nela Research Laboratory. The work is suited to use as a textbook and as a brief, comprehensive survey of the subject.

Induction Coils, in Theory and Practise.

By F. E. Austin. [Hanover, N. H., The author, 1919]. 64 pp., illus., diagrs., 9 x 5 in., cloth. $1.00.

A concise exposition of the fundamental principles of the induction coil, which will equip the student with the knowledge required for building coils to meet specified requirements. Data and specifications are given for coils giving ten, six and three inch sparks.

Manufacture of Pulp and Paper, v. 5.

By Joint Executive Committee of Vocational Education Committees of the Pulp and Paper Industry of the United States and Canada. N. Y., McGraw-Hill Book Co., 1925, various paging, illus., diagrs., plates, 9 x 6 in., cloth. $5.00.

This volume completes the textbook on pulp and paper manufacture prepared with the support of the pulp and paper manufacturers of North America. The work covers the entire field, including the necessary elementary knowledge of mathematics and natural sciences, and is intended for self-instruction as well as for class use. Much of the information has not been easily accessible hitherto.

The present volume deals with paper-making machines, hand-made papers, tub sizing, paper finishing, coated papers and the testing of papers. A bibliography on testing is appended to the last subject. There is also a selection on general mill equipment, pumps, electrical machinery, ventilation, lubrication and water.

Les Notions Fondamentales D'Element Chimique et D'Atome.

By Georges Urbain. Paris, Gauthier-Villars, 1925. (Science et Civilisation.) 172 pp., diagrs., tables, 8 x 6 in., paper. 10 fr.

This book is an attempt to give a general account of our present knowledge of the constitution of matter. The idea of the element, radioactive elements, the constituents of the atom and its constitution, the relation between the structure of the atom and its properties, and isotopes are the subjects successively treated.

The work, like the others in this series, is intended for readers with general interest in the subject rather than for specialists.

Origin of Continents and Oceans.

By Alfred Wegener. Trans. fr. the 3rd Ger. ed. by J. G. A. Skerl. N. Y., E. P. Dutton & Co., [1924]. 212 pp., illus., maps, 9 x 6 in., cloth. $4.50.

A presentation in English of the author's "displacement theory" of the origin of continents and oceans. Professor Wegener's hypothesis is that the continents are of lighter material and float like icebergs on a heavier plastic, that the poles are not fixed relative to the plastic, but have occupied widely different positions, and that the land masses are moving away from the poles and westwards. This movement has caused the separation of the continents. The book is devoted to the detailed establishment of this thesis.

A Popular History of American Invention.

By Waldemar Kaempffert. N. Y., Charles Schribner's Sons, 1924. 2 v., illus., ports., 10 x 7 in., cloth. $10.00.

The two attractive volumes that compose this work give the story of the invention and evolution of a number of important factors in our life. The development of our means of transportation, by railroad, electric railroad, canal and river, automobile and aircraft, is described. The evolution of modern printing and typesetting machinery, the typewriter, telegraph, telephone and radio apparatus, as well as of photography, the moving picture and the phonograph, is set forth. Another section deals with the steam engine and the generation of electricity, and a fourth with the growth of the industries—mining, lumbering and farming—that are concerned with the utilization of our material resources. The final section treats of automatic machine tools, pneumatic machines and the machinery used in the clothing and shoe industries.

The story is told in a very readable manner and well illustrated. Much attention is given to the inventors of the important machines in each group.

Principles of Transmission in Telephony.

By M. P. Weinbach. N. Y., Macmillan Co., 1924. (Engineering Science Series.) 303 pp., diagrs., tables, 9 x 6 in., cloth. $4.00.

Intended to give to students of telephone engineering a rigorous mathematical analysis of the problems that arise in modern telephone practise. While the fundamental ideas involved in electrical transmission are the same in telephony and heavy power transmission, the detailed development of the theory differs greatly, owing to the differences in frequency, variation of frequency, energy values and length of line; and it is to the careful study of the effect of these differences that this book is devoted.

Profitable Science in Industry.

By Dwight T. Farnham and others. N. Y., Macmillan Co., 1925. 291 pp., illus., 8 x 5 in., cloth. $3.50.

A book for business men, which calls attention to the results that have been achieved in various industries by active research work, by authors who are well known research workers in various fields. Attention is called to what has been done, to the opportunities that exist and to the organizations now actively engaged in such work. The book is readable and suggestive.

Railroad Accounts and Statistics.

By Charles E. Wermuth. N. Y., Prentice-Hall, Inc., 1924 349 pp., charts, 9 x 6 in., fabrikoid. $4.00.

According to the preface, this book aims to provide, in condensed form, a practical outline of present-day railroad accounting details and a description of their assembling to a completed financial statement, and also the theory and mathematics underlying the preparation of comparative statistics, with illustrations. The book is intended for railroad executives and students of railroad finance and accounting.

Recovery of Gasoline from Natural Gas.

By George A. Burrell. N. Y., Chemical Catalog Co., 1925. (American Chemical Society. Monograph series.) 600 pp. illus., diagrs., tables, 9 x 6 in., cloth. $7.00.

Beginning with a history of the industry from its inception, this book then treats of the occurrence and chemistry of natural gas and the methods of testing it for gasoline. The various processes for recovering gasoline are then explained and the construction and operation of the various types of plants are discussed in detail. Attention is given to depletion and also to motor fuels in general. The tables used in the industry are included. Dr. Burrell's comprehensive volume will fill a decided need.

Sammlung Elektrochemischer Rechenaufgaben.

By Gustav F. Huttig. Ber. & Lpz., Walter de Gruyter & Co., 1924. 102 pp., tables, 6 x 4 in., cloth. 1.25 gm.

A collection of the important conceptions, units and equations used by electrochemists, accompanied by problems which illustrate their use. Complete solutions of these problems are given. The book will be useful to students and also, as a convenient reference work, to electrochemists.

Subject List of the Periodicals in the Patent Office Library.

By Great Britain Patent Office Library. Lond., Patent Office, 1924. 282 pp., 7 x 4 in., paper. 2 s.

A catalog of the journals, transactions of societies, yearbooks, reports of permanent congresses and state and municipal departments, which are in the Library of the British Patent Office. The titles are classified under many subject headings, so that it is easy to find what periodicals are available in any given field of industry or science. Because of this arrangement, the list is also a useful guide for those who have access only to other libraries.

Time Measurement.

By L. Bolton. N. Y., D. Van Nostrand Co., 1924. 166 pp., illus., diagrs., 8 x 5 in., cloth. $2.00.

A brief account of the rudiments of the measurement of time, in which are described the more prominent natural phenomena suitable for this purpose and the machines constructed for it. A good introduction to the subject for those who wish to know how clocks, watches and electric clocks are made.

Untersuchungen uber die Gas-und Ol-Gleichdruckturbine.

By Wilhelm Gentsch. Halle (Saale), Wilhelm Knapp, 1924. 123 pp., tables, 10 x 7 in., paper. 5,20 m.

This work is a report, in detail, of an investigation of the Semmler gas turbine process which was made in 1904 and 1905 under the auspices of four leading German engine builders. In the Semmler process, the gas is burnt at constant pressure, the products of combustion are first used to heat a boiler and later when cooled to a workable temperature, used to drive a turbine.

The book is a welcome addition to the scanty literature on continuous combustion gas turbines, as it gives an account of practical investigations and the conclusion drawn from them.

Addresses Wanted

A list of names of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute headquarters promptly of any change in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

1.—E. T. Benderoth, 834 Golden Ave., Baryman Apt., Los Angeles, Calif.
2.—Clyde E. Bently, 2815 Kelsey St., Berkeley, Calif.
3.—Cyril St. C. Boland, 41 N. Jackson St., Atlanta, Ga.
4.—Edward F. Bradley, c/o So. Calif. Edison Co., Camp 62, Big Creek, Calif.
5.—W. T. Chappell, 3708 5th Ave., Pittsburgh, Pa.
6.—J. E. Contesti, 368 West 117th St., New York, N. Y.

7.—G. De La Rochette, c/o Westinghouse Elec. Int'l. Co., 2 Norfolk Strand, London W. C. 2, England.
8.—Thos. H. Endicott, 80 E. Jackson Blvd., Rm. 554, Chicago, Illinois.
9.—P. G. Fossatti, 3426 S. Michigan Blvd., Chicago, Ill.
10.—Harry N. Gilbert, 379 Cottage Ave., Glen Ellyn, Ill.
11.—William J. Gough, Box 230, Sea Cliff, L. I., N. Y.
12.—Harry A. Gould, So. Calif. Edison Co., 1201 W. 2nd St., Engg. Dept., Los Angeles, Calif.
13.—F. Leon Grajales, 710 No. Medina St., San Antonio, Texas.
14.—Thomas L. Henritze, P. O. Box 27, Pikeville, Ky.
15.—G. Hizawa, Mitsubiki Shoji Kaisha, 51 Chome Urakucho, Tokyo, Japan.
16.—William B. Hoey, High Tension Supplies Co., Wilmington, Del.
17.—F. M. Kenney, 611 North Lime St., Lancaster, Pa.
18.—H. D. Lamberton, 276 Keith Road East, N. Vancouver, B. C., Can.
19.—I. J. Larson, 71 Roseville Ave., Newark, N. J.
20.—W. L. McGeehan, c/o Ohio Power Co., Philo, Ohio.
21.—Austin W. Moore, 63 W. Parker St., Scranton, Pa.
22.—Wm. Spiel Norton, 10 Grove St., New York, N. Y.
23.—David M. Oseroff, 505 12th St., Brooklyn, N. Y.
24.—H. J. Phillip, 1617 So. Burlington St., Los Angeles, Calif.
25.—A. Shohan, Lombard, Ill.
26.—Gilbert H. Strand, Western States Gas & Electric Co., Camp R, Placerville, Calif.

Past Section and Branch Meetings

SECTION MEETINGS

Akron

Effects of Corona on Rubber, by F. L. Haushalter, B. F. Goodrich Co. Three motion pictures, entitled respectively "The Electrical Giant," "Beyond the Microscope" and "Five Big Deeds in the Electrical Industry," were shown. March 6. Attendance 55.

Atlanta

Developmenis in Long-Distance Radio Telephony, by A. A. Oswald, Bell Telephone Laboratories. Illustrated with slides, and

Radio Reception, by H. E. Bussey, General Electric Co. January 30. Attendance 93.

Boston

Railroad Electrification, by A. H. Armstrong, General Electric Co. Illustrated by slides. February 19. Attendance 75.

Cincinnati

Radio Interference, by Professor A. M. Wilson. Slides were shown. February 12. Attendance 68.

Cleveland

Inspection trip to Lake Shore Station of the Cleveland Electric Illuminating Co. January 22. Attendance 199.

Radio Broadcasting and Commercial Signaling, by E. F. W. Alexanderson. Slides were used to describe the American station of the trans-Atlantic system of the Radio Corporation of America. February 12. Attendance 85.

Columbus

New Self-Excited Synchronous Induction Motors with Constant Synchronizing Torque, by Val A. Fynn. Illustrated. The speaker also gave an interesting talk, with slides, of his experiences in mountain climbing. February 27. Attendance 52.

Connecticut

Electrification of Railroads, by A. H. Armstrong, General Electric Company. February 20. Attendance 75.

Denver

The Oscillograph and Its Applications, by H. M. Richardson. Illustrated by slides and blackboard sketches. February 20. Attendance 60.

Detroit-Ann Arbor

Inductive Coordination, by W. V. Lovell, National Electric Light Association, and D. H. Keyes, American Telephone and Telegraph Company. February 17. Attendance 75.

Erie

The Manufacture of Railway Motors, by Don F. Smith, General Electric Co. Illustrated with slides. February 17. Attendance 210.

Fort Wayne

Annual Dance. January 22. Attendance 80.

Automatic Stations and Their Remote Supervision, by Chester Lichtenberg, General Electric Co. Illustrated by moving pictures and slides. February 19. Attendance 65.

Indianapolis-Lafayette

City Distribution of Electrical Energy, by E. C. Ralston, Indianapolis Light and Heat Co. February 27. Attendance 45.

Ithaca

Mechanical Telephone Systems for Large Cities, by E. H. Goldsmith. January 16. Attendance 100.

A New Type of High-Tension Insulator, by Professor H. B. Smith. February 27. Attendance 120.

Los Angeles

The Electrical Industry—Past, Present and Future, by Robert M. Davis, *Electrical World*, Illustrated by slides. February 10. Attendance 97.

Madison

Static and Some Methods of Elimination, by Professor Terry, University of Wisconsin, and

Some of Milwaukee's City-Planning Problems, by Mr. Schuchardt, Milwaukee. February 20. Attendance 200.

Mexico

Business Meeting. September 4. Attendance 26.

Signalling and Switching, by Mr. Skarbovik. October 2. Attendance 9.

Power-Factor Correction, by Mr. Ramirez. November 6. Attendance 17.

Three films, entitled respectively "La Consolidada," "Thomas Alva Edison" and "Club de Los Afligidos," were shown. December 4. Attendance 41.

The Electric Locomotive, by Mr. Ramirez, and

The Electrification of the Mexican Railway, by Mr. Hawkins. A film, entitled "Queen of the Rails" was shown. January 8. Attendance 32.

A film, entitled "White Coal," was shown. February 5. Attendance 32.

Milwaukee

The Flow of Liquids in Pipes, by Professor Chas. I. Corp, University of Wisconsin. February 18. Attendance 100.

Sewage Disposal and Water Diversion through the Chicago Drain-Canal—Speakers: Messrs. T. C. Hatton, Chief Engineer, Sewerage Commission, H. L. Ekern, Attorney General of Wisconsin, W. F. Ardren, Milwaukee Western Fuel Company and Wm. G. Bruce, President of the Great Lakes Harbor Association. March 6. Attendance 400.

Minnesota

Testing of Hydroelectric Equipment, by G. L. Laughland, H. M. Byllesby Engineering and Management Corporation. A film illustrating the manufacture of storage batteries was shown. January 26. Attendance 46.

New York

The Engineer as a Railroad Executive, by Julius Kruttschmitt, Chairman, Southern Pacific System, and

The Engineer as an Executive, by Samuel M. Vauclain, President, Baldwin Locomotive Works. A joint meeting of the New York Sections of the A. I. E. E., A. S. M. E., A. S. C. E., A. I. M. E. and the New York Electrical Society, March 18, 1925. Attendance 925

Philadelphia

Transmission, the Key to an Empire, by Ross B. Mateer, Philadelphia Electric Co., and

The Deleware River, a Challenge to the Conservationists, by P. P. Wells, Deputy Attorney General, Commonwealth of Pennsylvania. February 18. Attendance 156.

Pittsburgh

Motor Maintenance, by F. R. Phillips, Pittsburgh Railways Company. The speaker called particular attention to the decrease in maintenance cost and the improvement in service resulting from adequate inspection. Refreshments were served. February 10. Attendance 375.

Pittsfield

The Art of Paper Making, by R. H. Rogers, General Electric Co. The speaker dealt particularly with the wood-pulp industry in its bearing on paper making. February 17. Attendance 225.

Lightning Arresters: What They Do and How They Do It, by Karl B. McEachron, General Electric Co. March 3. Attendance 125.

Portland

Standard Government and Control of Automobile Headlights, by Frank Pim. Refreshments were served. February 11. Attendance 50.

Providence

Effect of Furnace Mixtures on the Scaling of Steel, by Forest Manker, Surface Combustion Co. Illustrated. February 25. Attendance 100.

General Aspects of the Machine Switching, by H. C. Baker, Providence Telephone Co. March 10. Attendance 50.

Rochester

An illustrated talk was given by Professor H. B. Smith on his travels in India. January 30. Attendance 17.

Schenectady

Testing Impregnated-Paper Insulated Lead-Covered Cables, by E. S. Lee. January 23. Attendance 200.

In the Lands of Mohammed, by Professor Harold B. Smith. Illustrated. February 13. Attendance 570.

Seattle

The Economies of Transmission-Line Design, by Professor E. A. Loew, University of Washington. January 21. Attendance 68.

Springfield

The Magnetic and Electric Survey of the Oceans on the Non-Magnetic Yacht "Carnegie," by Captain J. P. Ault, Carnegie Institute. Illustrated with slides and motion pictures. February 9. Attendance 159.

Syracuse

Street Lighting, a Municipal Problem, by Professor R. D. Whitney. February 9. Attendance 23.

Travels in the Lands of Mohammed, by Professor H. B. Smith. February 26. Attendance 16.

Toledo

Putting the Gyro to Work to Make a True North Compass, or to Prevent Rolling of Ships, by R. B. Lea, Sperry Gyroscope Co. Illustrated. February 18. Attendance 96.

Toronto

Transmission-Line Relay Practise with Operating Experiences, by D. A. McKenzie. February 13. Attendance 113.

Tests on 54,000-Kv-a. Generators at Queenston Generating Station of the Hydro-Electric Power Commission, by B. L. Barns, Canadian General Electric Co. February 27. Attendance 65.

Urbana

The Electricity Supply Industry and the Engineer, by R. F. Schuchardt. February 27. Attendance 90.

Utah

The Profession of Engineering, Its Antiquity and Obligation, by Dr. Wm. F. Durand, President, A. S. M. E. February 18. Attendance 117.

Washington

Automatic Substations and Their Remote Supervision, by Chester Lichtenberg. Illustrated by lantern slides and motion pictures. February 10. Attendance 53.

Worcester

Automatic Stokers, by F. H. Daniels, Riley-Stoker Corporation. February 26. Attendance 35.

BRANCH MEETINGS

Alabama Polytechnic Institute

"Panana Canal" was the title of the film shown. A number of informal talks on the Canal were given. February 18. Attendance 62.

Transformers, by Geo. H. Taylor, student. Illustrated with slides. February 25. Attendance 51.

Business meeting. March 4. Attendance 24.

Inspection trip to the North Auburn Sub-Station of the Alabama Power Company; also to an engineering project on the Central of Georgia Railway. March 7. Attendance 38.

Business Relations and the Engineer, by Professor A. T. Thomas. March 11. Attendance 36.

University of Alabama

The Control of Electric Motors, by F. R. Fishback, Electric Controller & Mfg. Co. February 3. Attendance 39.

University of Arkansas

A motion picture, entitled "Acetylene Welding," was shown. A lecture accompanied the picture, which gave an explanation of different processes of welding and brazing, including the new bronze weld. February 17. Attendance 32.

Armour Institute of Technology

A talk was given by W. E. Dean, student, in which he explained the part electricity plays in the preparation of milk for use by the public. February 26. Attendance 35.

Bucknell University

The Development of the Communication Act, by J. H. Bigelow, New York Telephone Co. Illustrated with slides. February 16. Attendance 55.

California Institute of Technology

A New Type of Single-Phase Motor, by A. E. Schueler. February 4. Attendance 25.

The Past, Present and Future of the Electrical Industry, by R. M. Davis, *Electrical World*. Illustrated with slides. February 9. Attendance 40.

Automatic Telephone Equipment, by Carter Austin, student. March 4. Attendance 27.

University of Cincinnati

The Market Price of an Electrical Engineer, by C. T. Button. February 5. Attendance 63.

Electrical Engineers and Dollars, by R. T. Congleton. January 22. Attendance 52.

Clarkson College of Technology

What the American Institute of Electrical Engineers Is, by Mr. Criter. Luncheon was served. February 10. Attendance 29.

The Oscillographer, by Professor Powers. February 24. Attendance 17.

Clemson Agricultural College

Electric Shovels, by J. M. Van de Erve,

Electric Light Development in America, by B. V. Martin, and *Automatic Sub-Stations*, by R. E. Hall. March 5. Attendance 17.

University of Colorado

The Fynn-Weichsel Motor, by Mr. Cartwright. Illustrated with slides. February 18. Attendance 38.

The Oscillograph and Its Uses, by Henry Richardson, student. Illustrated with slides, demonstrating the use of the oscillograph in investigating both transient and recurrent phenomena. Short talks were also given by Fritz Johnson and Lester Simpson, students. A banquet was served before the meeting. February 20. Attendance 45.

University of Denver

The Multiplex Printing System of the Telegraph, by Ray Hoover. February 13. Attendance 22.

Importance of the Telephone, by A. D. Spaulding. A practical telephone switchboard demonstration was given by the Mountain States Telephone and Telegraph Co. Motion Pictures were shown. Joint meeting with Y. M. C. A. March 5. Attendance 200.

Power-Plant Lubrication, by F. R. Schmidt. The speaker explained the characteristics of parafine and asphalt base oils, and

Oil Circuit Breakers and Control, by E. E. Weyerts. March 6. Attendance 18.

University of Florida

Business Meeting. The following officers were elected: President, Professor J. Weil; Secretary, C. Washburn, Jr. January 19.

Iowa State College

Business Meeting. January 22. Attendance 7.

Two moving pictures were shown;—one on the Electrification of Railroads and the other on the Manufacture of Mazda Lamps. February 25. Attendance 66.

Lafayette College

Talk by Professor King on some of the places visited during the Midwinter Convention of the Institute. February 14. Attendance 16.

Marquette University

Power Transmission of the Future, by W. S. Wilder, T. M. E. R. & L. Co. The speaker pointed out how the transmission of direct current was dependent upon the future developments in high-power electron tubes, and also went into the details of the operating principles of electron tubes. February 19. Attendance 26.

Michigan Agricultural College

Electrical Show. Senior and Junior Electrical Engineering students staged a three-day electrical show. Many interesting exhibits were shown, including a model hydroelectric plant and a model steam generating plant, a small portable broadcasting station, radio equipment, commercial domestic electrical appliances and various experimental apparatus. February 23, 24 and 25. Total attendance 1500.

University of Michigan

The Engineer's Duty as a Citizen, by George Lewis, Mayor of Ann Arbor. The meeting was in the form of a smoker. March 3. Attendance 75.

School of Engineering of Milwaukee

The Proposed New Power-Plant at the Holeproof Hosiery Company, by S. A. Moore. February 26. Attendance 20.

University of Missouri

Electrical Generating System of a Modern Warship, by R. E. Johnson, student. February 16. Attendance 20.

University of Nevada

Business Meeting. February 24. Attendance 25.

University of North Carolina

A 40,000-Kv-a Generator, by J. Fred Kistler, and

A New Dam Construction, by R. J. Rosenberger, student. January 29. Attendance 16.

High-Frequency Resistance and Methods of Measuring It, by Mr. Grey, and

Low-Loss Coils in Radio, by O. R. Rowe. February 12. Attendance 20.

Business Meeting. The following officers were elected: Chairman, C. L. Jones; Vice-Chairman, Chas. Ray; Treasurer, Frank Waldhurst; Secretary, J. F. Kistler. February 26. Attendance 35.

University of North Dakota

Muscle Shoals, by Helmer Gronhovd, student. February 23. Attendance 12.

Design of a 65,000-Kv-a. A. C. Generator, by O. B. Medalen, student. March 9. Attendance 16.

Northeastern University

Sales Engineering, by G. C. Lamb, Condit Electric Mfg. Company. The following officers were elected: Chairman, E. H. Barker; Vice-Chairman, E. J. Perkins; Secretary-Treasurer, C. M. McCoombe; Assistant Secretary-Treasurer, H. F. Kingsbury. Refreshments were served. January 12. Attendance 31.

Inspection trip to the Holtzer Cabot Plant in Jamaica Plain. February 8. Attendance 33.

Ohio Northern University

Oil Engines as Prime Movers for Electrical Generators, by Max Lee, and

High-Tension Electrical Construction, by H. J. Relihan. February 18. Attendance 37.

Ohio State University

History of the Atlantic Cable, by A. J. Mundt, Western Union Co. February 13. Attendance 110.

Japanese Dido Properties, by S. Q. Hayes, Westinghouse Electric & Mfg. Co. Illustrated. March 2. Attendance 60.

Control of Electric Motors, by F. R. Fishback, Electric Controller and Mfg. Co. Illustrated with slides. February 27. Attendance 15.

Oregon Agricultural College

Business Meeting. January 29. Attendance 38.

University of Pennsylvania

First Annual Banquet. Addresses were made by Dr. W. C. L. Eglin, Philadelphia Electric Co., Professor C. D. Faucette, Dean Harold Pender and Professor C. E. Clewell. February 11. Attendance 90.

Business Meeting. March 5. Attendance 75.

Student Branch Convention. March 9. Attendance 300. See page of this issue.

University of Pittsburgh

Material Handling, by R. A. McGregor, Lakewood Engineering Co. January 9. Attendance 80.

Gas-Electric Automobile, by A. P. Kilgallon, and

The Engineer—an Educated Man, by G. S. Dively. January 16. Attendance 24.

Short-Wave Radio Broadcasting, by C. W. Dalzell. January 23. Attendance 26.

Carrier-Wave Telephony, by H. A. Thompson, and

Artificial Transmission Lines, by J. E. Lange. February 13. Attendance 23.

Purdue University

News-Print Paper in North America, by R. S. Kellogg, News Print Service Bureau. February 24. Attendance 47.

Electric Heating and Its Application to Industry, by Mr. Piper, Westinghouse Company. Illustrated with slides. February 25. Attendance 34.

A motion picture, entitled "Power," was shown. March 5. Attendance 135.

Rensselaer Polytechnic Institute

Alternating-Current Machinery, by C. M. Cogan, General Electric Co. February 17. Attendance 148.

Experiences College Men Go Up Against and Have to Meet After Graduation, by Farley Osgood, National President, A. I. E. E. March 10. Attendance 239.

Rutgers University

Artificial Representation of Power Systems, by E. N. Sieder, student. February 16. Attendance 8.

South Dakota State School of Mines

Electrification of Steam Railroads, by Professor Kammerman. Motion pictures on the uses of X-Rays were shown. The following officers were elected: Chairman, E. W. Barnes; Secretary-Treasurer, V. Walrod. Refreshments were served February 16. Attendance 30.

Stanford University

The Stability of Large, Interconnected Power Distribution Systems, by F. R. George, Pacific Gas & Electric Co. Illustrated with slides, —showing conditions under which the systems must operate. February 17. Attendance 28.

Syracuse University

The Frequency-Changing Apparatus of the Salmon River Power Company, by Mr. Kaufman. January 7. Attendance 25.

Multiple Telegraphy, by R. J. O'Neill. January 14. Attendance 24.

The Electrification of Steel Mills, by F. A. Bothwell. February 10. Attendance 23.

Texas Agricultural and Mechanical College

Conductorless Electric Circuits, by D. G. Bell. February 27. Attendance 87.

University of Texas

The Work Done by Graduates in the General Electric Company, by M. M. Boring. February 5. Attendance 29.

A film, entitled "Beyond the Microscope," was shown. February 20. Attendance 60.

University of Utah

Regenerative Braking, by H. T. Plumb, General Electric Co. December 9. Attendance 90.

The Advantages of Belonging to the A. I. E. E., by L. B. Johnson, General Electric Co. February 11. Attendance 25.

Virginia Military Institute

The Recent Development of the Internal-Combustion-Engine Electric Locomotive, by S. W. Marshall.

Value of Testing Magnetic Materials, by Mr. Warwick. A short talk was given by Col. S. W. Anderson in which he pointed out how valuable it is for a young engineer to get his name before the public. February 11. Attendance 41.

Electrical Machinery in Steel Mill Operation. Illustrated. February 19. Attendance 43.

Two motion pictures, entitled respectively "The Electrification of Railways" and "The Single Ridge," were shown. March 9. Attendance 22.

Virginia Polytechnic Institute

The History of Radio, by M. R. Staley.

A Comparison of Radio Receiving Sets, by K. H. Kellar,

Chemical Rectifiers, by T. A. Keck, and

Superpower Transmission, by E. M. Melton. February 16. Attendance 32.

University of Virginia

Business Meeting. January 20. Attendance 15.

A motion picture, entitled "White Coal," was shown. February 17. Attendance 17.

Washington University

Motion picture, entitled "An Electrified Travelogue," was shown. February 10. Attendance 12.

Business Meeting. February 26. Attendance 20.

University of Washington

Power Development of the Puget Sound Light & Power Company, by R. Rader, Puget Sound Power and Light Co. February 3. Attendance 29.

West Virginia University

Engineering Prospects, by Mr. Addis,

Direct-Current Machines for Merchant-Marine Drive, by Mr. Crush.

Influence of Radio on Power Development, by Mr. Meintel, and

Edison Medal Awarded to John White Howell, by Mr. Neill. February 13. Attendance 25.

Cement Plant of the Alpha Portland Cement Company, by Mr. Wolfe,

The Operation of Synchronous Converters at Reduced Voltages, by Mr. Devebre,

Insulators, by Mr. Roush, and

Development of the Incadescent Light, by Mr. Worden. February 27. Attendance 23.

University of Wisconsin

Talks were given by students on their Summer work in industrial practise. December 2. Attendance 20.

A motion picture, entitled "The Manufacturing of Electric Cables," was shown. The following officers were elected: Chairman, H. C. Wolfe; Secretary-Treasurer, N. G. Robisch; Executive Committee, H. G. Berger and W. H. Dresser. Joint meeting with A. S. M. E. February 11. Attendance 20.

Yale University

Industrial Illumination, by J. L. Buttolph, Cooper-Hewitt Electric Co. February 10. Attendance 60.

The Mathematics of Investment, by Professor W. A. Wilson. March 4. Attendance 50.

The Evolution of Society, by Professor A. G. Keller. March 11. Attendance 65.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers as a cooperative bureau available only to their membership, and maintained by contributions from the societies and their individual members who are directly benefited.

MEN AVAILABLE.—Brief announcements will be published without charge and will not be repeated, except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case and with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

ENGINEER, with excellent technical training and interested in engineering work with insulation and processes. Some chemical training desirable. Young man preferred though previous experience will be of value. Apply by letter stating training, experience, age and salary expected. Location, East. R-5595.

ENGINEER, about 35, to take charge of experimental laboratory. Must have good mechanical and electrical foundation. Man with a record behind him. Location, Middlewest. R-5443.

RADIO ENGINEER, preferably young, with technical education. Location, Middlewest. R-5422.

GRADUATE ENGINEER, experienced in power plant work, with business ability to qualify for executive position by making good in the designing, erecting and selling department of company manufacturing cooling towers. Apply by letter. Location, East. R-5866.

ESTABLISHED, growing and profitable consulting engineering (mechanical and electrical) business in New York City would consider adding a partner, who is an experienced engineer of prominence, for purposes of expanding its business. No cash investment necessary. Would also consider consolidation with similar business. R-5883.

MEN AVAILABLE

MECHANICAL AND ELECTRICAL ENGINEER, inventor, age 36, member A. S. M. E., and A. I. E. E. Proficient in research, design, experimental, efficiency in radio, automotive and medical apparatus. B-9035.

ELECTRICAL CONSTRUCTION ENGINEER, DESIGNER, DRAFTSMAN, thoroughly accurate in electrical and mechanical work, reliable, with long experience in automatic switches, brush switches with maximum and minimum breakers up to 10,000 ampere, also in lubricating high tension switches, releases and measuring instruments. B-4968.

ELECTRICAL ENGINEER, technical graduate, 37, married, two years university teacher, nine years with public utilities. Experienced in design, construction, maintenance and operation of public utilities. Well versed in office routine, rates, accounts, purchasing, etc. Completed Alexander Hamilton Business Course. Desires executive position as general superintendent, manager, assistant to president. Available

reasonable notice. Minimum salary $7500. B-9480.

TECHNICAL GRADUATE, M. E., E. E., Ch. E., 33, five years apprenticeship with manufacturer electrical, also refrigerating equipment. One year development work. Five years responsible charge design, construction, maintenance of paint, dye, chemical plants. Experience sale of pumps and electrical machinery. Desires special problem or development work with organization located in Middlewest. Salary $4500. B-1738.

ELECTRICAL GRADUATE, extensive experience with large manufacturing firm, in power switchboard work. Would like opportunity with industrial or utility where a general knowledge of electric power problems would be useful, in Canada, preferably Ontario or Quebec. B-9500.

MAN with ten years' practical experience in testing A. C. and D. C. meters and generators, electrical maintenance. Will graduate June 1, 1925 in electrical engineering. Wishes a position either in sales, or in experimental work Single. Will go anywhere, but prefers Midwest. B-9467.

GRADUATE ELECTRICAL ENGINEER, age 30, married, six years good general experience in design, operation and maintenance of power plants and transmission system. Desires position with public utility or electrical manufacturer with opportunity to specialize. Middlewest or West preferred. Minimum salary $2400. Available on reasonable notice. B-9474.

ELECTRICAL ENGINEER, M. I. T. '13, has had varied experience including teaching, research, army, plant engineering and sales engineering. Desires position as assistant plant engineer or construction engineer in large oragnization, preferably South or Southwest. Available immediately. B-9455.

ELECTRICAL ENGINEER, technical graduate, age 26, married, two and one-half years with W. E. Manufacturing Company. Argentine nationality, speaks Spanish, English, Italian and understands French. Wants a position with a company to work in Argentine in electrical engineering work. Available in one month. B-9454.

ASSISTANT PROFESSOR OF ELECTRICAL ENGINEERING, age 32, married, four years of teaching experience, lecture, laboratory, design. Seven years of railway, shop, telephone and power work. Available in September. B-972.

ELECTRICAL ENGINEER, age 27, one and one-half years research, one and one-half years teaching, some power plant and test floor experience. Desires teaching position. Available after July first. B-7263.

ELECTRICAL ENGINEER, technical graduate, age 26, desires responsible position with a growing electrical concern; production, installation or radio development. Experienced in motor work, installation, wiring, storage batteries. One with opportunity for advancement desired. Available the middle of April. Location, New York City or New Jersey. B-9353.

POWER SALESMAN, age 28, single, broad experience in highly diversified industrial region. Rate experience, competent to make, establish, sell and maintain power factor rate. Desires opportunity with progressive utility, in executive capacity, in power sales. Any location. Available three weeks. B-9487.

ELECTRICAL ENGINEER, technical education, experienced in the design of poly phase induction and direct current motors, desires position with an electrical motor manufacturing company as motor designer. Twenty-four years' experience in designing and development of alternating and direct current motors. Investigation, service work, electrical construction and maintenance. B-9016.

RELAY ENGINEER, technical education, 37, three years' service department Westinghouse, six years in charge relay division large central station. Developed testing methods, equipment, record systems for relays, system of analysis for interruptions, etc. Wishes position protective engineering department, or will undertake organization of relay test, maintenance division. Available five weeks' notice. B-9503.

RECENT ELECTRICAL ENGINEERING GRADUATE, age 24, single, desires position preferably with public utility. Have made an extensive study of the public relations field, and have had some business, sales and engineering experience. Prefer administrative, or combined administrative and engineering position, but would consider any engineering work, especially development and perfection of equipment and patents. Available on short notice. B-9528.

SUPERINTENDENT, age 38, married, twenty years' experience in construction, maintenance and operation of substations, power installations, meters and relays. At present and for the past eight years contractor in New York City. Available thirty days. B-9539.

TECHNICAL GRADUATE, 1914, married, desires employment with organization requiring services of engineer and executive of proved ability, experience. Two years' supervising educational training; one year superintendent maintenance electric railway. Captain coast artillery, now major officers' reserve corps. Five years telephone equipment engineer specializing in power work. Available sixty days. B-9568.

RADIO ENGINEER, B. S. of E. E., married, experienced in the design of radio frequency amplifiers and entire receivers. Familiar with test apparatus, also have teaching, broadcasting and signal corps experience. Associate Institute of Radio Engineers. Available on short notice. B-9544.

ENGINEER, B. S. and E. E. degrees, fifteen years' experience testing, construction, design and supervision of substation and distribution work. Desires connection with manufacturer, public utility, engineer or investment banker employing engineers. Available on one months' notice. B-9551.

GRADUATE ELECTRICAL ENGINEER, young, with six years college training and experience in research and development work, also two and one half years' teaching. Desires permanent connection with organization where experience could be capitalized and the possibilities for expansion are present. Location preferred, West, Middlewest or South. B-7498.

JUNIOR TECHNICAL SALESMAN, technical school graduate, age 29, single, one year of inspection and public utility work, four years' practical experience in various electrical lines. Desires to enter sales field, New York district preferred. Available reasonable notice. B-7920.

ELECTRICAL AND MECHANICAL ENGINEER, with executive training, experienced in economical power plant operation; combustion, uses or steam, turbines, generators, industrial electrical layout, motors, controllers and their applications, factory maintenance and construction. Available immediately. B-8448.

ELECTRICAL ENGINEER, age 25, single, Canadian, with eighteen months' test experience with the Canadian Westinghouse Company, desires a position in an engineering firm. Very good references. Available at end of April. B-9570.

FIELD ENGINEER, 28, married, graduate electrical engineer 1920. One year G. E. test, two years power plant operation and construction, two years construction of transmission and distribution substations. Desires similar position with consulting engineer or public utility. Would consider position in power sales or sales engineering. B-6010.

ELECTRICAL CONSTRUCTION FOREMAN, age 40, twenty years' experience power plant and substation construction. Good following of A-1 journeyman. Available at once. B-9571.

ELECTRICAL ENGINEER, age 30, technical school graduate, twelve years' experience on construction, installation, maintenance and inspection of light, power and signal systems. Has also worked in the capacity of assistant consulting engineer, sales engineer and branch manager, instructor and technical writer. Desires change with future for executive work. Location optional. B-247.

UNIVERSITY GRADUATE, 28, one and one-half years' electrical shop construction, maintenance experience, one year with one of largest power distributors at transmission line survey, location, inspection, office drafting. Desires permanent position at transmission line substation drafting, design, preferably North Central states or Eastern Canada. $135 a month with opportunity. Available one month. B-9556.

ASSISTANT PROFESSOR OF ELECTRICAL ENGINEERING in leading southern technical school desires opportunity for more rapid advancement in teaching profession, or position of responsibility in executive work. Age 27, married, graduate University of Missouri, 1921 with B. S. in E. E. Two years' electrical engineering experience and two years' teaching experience. B-6303.

INDUSTRIAL ENGINEER, electrical and mechanical, 35, married; specialist design, application, installation of automatic electric control apparatus and devices. Experience also covers railway signal, steam power plant operation, electrical and mechanical construction field. Electrical and mechanical draftsman. Reasonable legitimate offers considered. Minimum $225.00. Correspondence solicited. Central West or Southern States only. B-9561.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED MARCH 13, 1925

*ADAM, LOUIS GEORGE, Technical Employee, American Tel. & Tel. Co., 311 W. Washington St., Chicago, Ill.

*ADAMS, GEORGE G., Tester, New York Edison Co., 92 Vandam St., New York; res., Jamaica Oaks, N. Y.

ALLDRIDGE, LESTER, Electrical Engineer, American Radio & Electric Co., Inc., 111-121 Kossuth St., Union Hill, N. J.; res., Brooklyn, N. Y.

ALLEN, HOWARD BRIGHAM, Sales Engineer, Westinghouse Electric International Co., 150 Broadway, New York; res., Brooklyn, N. Y.

*ALLEN, THOMAS TWADDEL, Electrician, Jos. T. Fewkes & Co., 137 N. 12th St., Philadelphia, Pa.

ALLGEIER, OWEN R., Engineer, Union Electric Light & Power Co., and the St. Louis County Gas Co., Lockwood & McClure Aves., Webster Groves, Mo.

AMANN, RUDOLPH E., Draftsman, Buffalo Forge Co., 490 Broadway, Buffalo, N. Y.

ANDERSON, LOUIS NORMAN, Technical Supervisor, All America Cables, Inc., U. S. Naval Station, Guantanamo Bay, Cuba.

ANDREW, CHARLES JAMES, Jr., Electrical Draftsman, Kansas City Power & Light Co., 1330 Grand Ave., Kansas City, Mo.; res., Kansas City, Kans.

*APOSTAL, SPEROS D., Circuit Engineer, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.

ARCHER, WILLIAM WHARTON, Jr., Construction Engineer, Virginia Railway & Power Co., Richmond, Va.

ARNTZEN, BRANDT, Draftsman, New York & New Jersey State Bridge & Tunnel Commission, 233 Broadway, New York; res., Brooklyn, N. Y.

ATKINSON, GEORGE EVLIN, Clerk, Toledo Edison Co., Acme Station, Toledo, Ohio.

BARCLAY, AMOS EWING, Asst. Electrical Engineer, Dwight P. Robinson & Co., Inc., 125 E. 46th St., New York, N. Y.

BEARD, ROBERT FLEMING, Philadelphia Mgr., Electrical Merchandise, Industrial Engineer, *Journal of Electricity*, 712 Real Estate Trust Bldg., Philadelphia, Pa.

*BEARDSLEY, FRANK DEY, Student Engineer, Testing Dept., General Electric Co., Schenectady, N. Y.

BECKER, NIELS RICHARD ALWYN, Commercial Agent, Michigan Bell Telephone Co. of Detroit, Mich.; res., Jacksonville, Fla.

BENJAMIN, ROY M., Electrical Service Inspector, Bureau of Power & Light, 120 E. 4th St., Los Angeles, Calif.

*BENNETT, RICHARD HEBER, Jr., Electrical Engineer, Relay Dept., Tennessee Electric Power Co., Chattanooga, Tenn.

*BERGSTROM, THEODORE, 1414 W. 62nd St., Seattle, Wash.

*BEST, C. A., Engineer, The Pacific Tel. & Tel. Co., Fresno, Calif.

BIEGEL, EARL JULIUS, Material Man, Duquesne Light Co., 604 Chamber of Commerce Bldg., Pittsburgh; res., Wilkinsburg, Pa.

BIRGE, EDGAR BRAZILL, Tester, Brooklyn Edison Co., 360 Pearl St., Brooklyn, N. Y.; res., Weehawken, N. J.

BJORNDAL, MAGNUS, Electrical Draftsman New York Edison Co., 44 E. 23rd St., New York, N. Y.

*BLOMQUIST, ERNEST PHILIP, Electrical Draftsman, Densmore, LeClair & Robbins, Park Sq. Bldg., Boston; res., Jamaica Plain, Mass.

BOLL, LESTER PIERCE, Distribution Engineer, Union Electric Light & Power Co., Lockwood & McClure Aves., Webster Groves, Mo.

*BOUSMAN, HENRY WOODFORD, Apprentice, Allis-Chalmers Mfg. Co., 477 68th Ave., West Allis, Wis.

BREUNIG, ROBERT HENRY, Maintenance Electrician, Atlantic City Electric Co., Philadelphia, Pa.

BRIDDICK, JOHN WILLIAM, Manager, Machinery Insurance Dept., Barker, Grost & Chapman Co., Toledo, Ohio.

*BROWN, HAROLD CARL, Meter Engineer, Westinghouse Elec. & Mfg. Co., 467 10th Ave., New York; for mail, Walden, N. Y.

*BROWN, LELAND HERMON, Electrical Engineer, Crystal Lake Laboratory, Cassel, via Redding, Calif.

*BURNS, DAVID, Engineer, Detroit Edison Co., 2000 Second Ave., Detroit, Mich.

CARNAGY, LESLIE WARREN, Southern Manager, Locke Insulator Corp. of Baltimore, Md., 414 Red Rock Bldg., Atlanta, Ga.

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*SCHNEIDER, ELMER THOMAS, Tester, The New York Edison Co, 92 Vandam St., New York; res., Brooklyn, N. Y.
SCHRAY, RALPH R. Manager & Electrical Engineer, Akron Motor & Generator Repair Co., 39 N. Valley St., Akron, Ohio.
SCHREGARDUS, DIRK, Telephone Engineer, Ohio Bell Telephone Co., 4300 Euclid Ave., Cleveland, Ohio.
*SCHULTZ, SOL ELI, Distribution Engineer, Consumers Power Co., Michigan Ave., West, Jackson, Mich.
SCHWEIZER, FRED WILLIAM, Elec. Engg. Dept., Brooklyn Edison Co., 360 Pearl St., Brooklyn, N. Y.
*SEAMAN, KERMIT GEORGE, Asst. Field Engineer, Public Service Co. of Colorado, Boulder, Colo.
*SEELEY, HOWARD B., Elec. Engg. Assistant. Inside Plant Bureau, Brooklyn Edison Co., Brooklyn, N. Y.
*SEIGMAN, PAUL CLIFFORD, Engineer, Philadelphia Suburban Gas & Electric Co., Wyncote; res., Easton, Pa.
SEVERE, L. J., Draftsman, Electrical Design, Pacific Gas & Electric Co., 375 Sutter St., San Francisco; Berkeley, Calif.
*SHAUGHNESS, CHARLES EDWARD, Jr., Law Student, Fordham Law School, Woolworth Bldg., New York; res., Brooklyn, N. Y.
SHEFFORD, JAMES HERBERT, Asst. Engineer, General Radio Co., Ltd., 22 & 23 Allsop St., London, N. W., England.
*SIDWELL, LEONARD WILFORD, Instructor, Elec. Engg. Dept., University of Utah, Salt Lake City, Utah.
SIGNEUL, RAGNAR, Designer, Stone & Webster, Inc., 147 Milk St., Boston, Mass.
*SKILLMAN, WILLIAM THOMAS, Asst. Engineer, New York Telephone Co., 104 Broad St., New York, N. Y.
*SKINNER, VERNON ORLA, Transmission & Protection Man, Illinois Bell Telephone Co., 212 W. Washington St., Chicago, Ill.
SKOGLUND, CHARLES, Engineer, Wire & Insulations, River Works, General Electric Co., Lynn, Mass.
*SLEEMAN, HAROLD PARKER, Asst. Electrical Engineer, The R. Thomas & Sons Co., East Liverpool, Ohio.
*SMITH, CHARLES COBB, Engineer, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.
SMITH, LEONARD HUIA, 100 Moxham Ave., Hataitai, Wellington, New Zealand.
SNODGRASS, FRED C., Technical Employee, American Tel. & Tel. Co., 4300 Euclid Ave., Cleveland, Ohio.
STANSFIELD, DONALD WIEDER, Electrical Tester, Westinghouse Elec. & Mfg. Co., Sharon, Pa.
ST. DENIS, CHARLES WALTER, Salesman, Scanlon Supply Co., 1216 Pine St., St. Louis, Mo.
*STEARNS, MINER BRODHEAD, Section Chief, Testing, Western Electric Co., 1601 Glenwood Ave., Philadelphia, Pa.
STEBBINS, CHARLES, Chief Electrician, 12th St. Power Plant, Virginia Railway & Power Co., Richmond, Va.
*STEINER, JOSEPH LOUIS, Repair Man, New York Telephone Co., Dey St., New York, N. Y; res., Guttenberg, N. J.
*STEVENS, RICHARD FRANCIS, Student Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Sharon, Pa.
*STEWART, D. C., Chief Draftsman, Niagara, Lockport & Ontario Power Co., 605 Lafayette Bldg., Buffalo, N. Y.
STEWART, JOHN McCULLOCH, Student, Canterbury University College, Rolleston House, Christchurch; for mail, Canterbury, New Zealand.
STOCKTON, FRANK HAMILTON, Tester, Westinghouse Elec. & Mfg. Co., Sharon, Pa.
*STODDARD, RAYMOND ROBERT, Asst. Engineer, Stationary Motor Dept., General Electric Co., Lynn, Mass.
*STRAHAN, HENRY CLARK, Engg. Dept., Meter & Street Lighting Div., Central Hudson Gas & Electric Co., 50 Market St., Poughkeepsie; res., Arlington, N. Y.
*SUHR, HERBERT F., Switchboard Man, Wisconsin Telephone Co., 861 37th St., Milwaukee, Wis.
SUMMERS, HARRY ANDERSON, Member of Technical Staff, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
*SWIEDOM, E. ALVIN, Industrial Control Engineer, General Electric Co., Schenectady, N. Y.
*THOMPSON, ROBERT P., Field Man, Plant Engg. Dept., Pacific Tel. & Tel. Co., 416 W. 8th St., Los Angeles; res., Glendale, Calif.
THOMSON, CHARLES, General Superintendent, Otis Elevator Co. of Missouri, 2301 Locust St., St. Louis, Mo.
TODD, GEORGE CLINTON, Superintendent of Telegraph, Nickel Plate Railroad, 816 Columbia Bldg., Cleveland, Ohio.
*TRUBE, CARL EDWARD, Engineer, Thermiodyne Radio Corp., 70 Woodland Road, Maplewood, N. J.
*TUBBS, WESLEY EARL, Engineer, Distribution Engg. Dept., West Penn Power Co., 14 Wood St., Pittsburgh, Pa.
*TUCKER, WILMER H., Laboratory Engineer, The Hoover Co., North Canton; res., Canton, Ohio.
*TUITES, CLARENCE EDGAR, Resident Engineer, Consumers Power Co., Saginaw, Mich.
UNGAR, HANS, General Electric Co., Schenectady, N. Y.
VAN DERBARK, CLOMER GLENN, Electrical Draftsman, Kansas City Power & Light Co., 1330 Grand Ave., Kansas City, Mo.
*VAN KEUREN, ROBERT G., Adjustment Division, Norton Co., 1 New Bond St., Worcester, Mass.
VEITH, HERMAN EDWARD, Instructor, National Electrical School, 4006 South Figueroa St., Los Angeles; for mail, Glendale, Calif.
*VIETH, WILLIAM F., Asst. Engineer, Research Laboratory, Western Electric Co., Inc., 463 West St., New York, N. Y.
*VINCENT, HENRY LEASK, Sales Dept., General Electric Co., 701 Electric Bldg., 329 Alder St., Portland, Ore.
VOEPEL, ERWIN WILLIAM CLARENCE, Electric Service Engineer, Westinghouse Elec. & Mfg. Co., 717 S. 12th St., St. Louis, Mo.
VOORHEES, JOHN SHARP, Engineering Assistant, Brooklyn Edison Co., Pearl & Willoughby Sts., Brooklyn, N. Y.
*WARD, ALVIN C., Equipment Engineer, Western Electric Co., Inc., Chicago; res., Berwyn, Ill.
WEIS, JOHN E., Supervisor of Installation Div., Union Electric Light & Power Co., 315 N. 12th Blvd., St. Louis, Mo.
WERRES, CHRISTIAN OTTO, Electrical Engineer, General Engg. Lab., General Electric Co., Schenectady, N. Y.
WESTERMARK, ARTHUR, Electrical Service Inspector, Bureau of Power & Light, 120 E. 4th St., Los Angeles, Calif.
WHITMAN, VERNON ELEAZER, Asst. Physicist, Bureau of Standards, 108 E., Bureau of Standards, Washington, D. C.
WICKUS, RALPH W., Tester, Wisconsin Power & Light Co., 900 Gay Bldg., Madison, Wis.
WILDER, RALPH, Student, New York Electrical School, 39 W. 17th St., New York; res., Brooklyn, N. Y.
WILLIAMS, NORMAN GEORGE, Local Manager, Gov't Telephones, Melville, Sask., Can.
*WILLIAMS, THOMAS W., Engineering Assistant, The Bell Telephone Co. of Penna., 1230 Arch St., Philadelphia, Pa.
WILLIAMS, WILLIAM MERRILL, Century Electric Co., 1827 Pine St., St. Louis, Mo.
WINTER, PAUL, Operating Dept., Brooklyn Edison Co., 6 Gold St. Station, Brooklyn, N. Y.
WITKE, EMIL E., Instructor, National Electrical School, Figueroa & Santa Barbara Sts., Los Angeles, Calif.
WOODCOCK, WILLIAM IRVIN, Control Engineer, Westinghouse Elec. & Mfg. Co., 814 Ellicott Square, Buffalo, N. Y.
ZEGLIO, LEON PETER, Asst. Elec. Foreman, Hudson Ave. Gen. Sta., Brooklyn Edison Co., Pearl & Willoughby Sts., Brooklyn, N. Y.

Total 340

*Formerly Enrolled Students

ASSOCIATES REELECTED MARCH 13, 1925

CANSFIELD, CHARLES ERNEST, Manager, Cansfield Electrical Works, 62 LombardSt., Toronto, Ont., Can.
HARDIN, LEWIS HAMILTON, Electrical Engineer, Mees & Mees, 616 Johnson Bldg., Charlotte, N. C.
ROTH, RAYMOND, Sales Manager, 30 Church St., New York, N. Y.

MEMBERS ELECTED MARCH 13, 1925

BENEDICT, SEYMOUR D., Electrical Engineer, New York State Dept. of Architecture, Room 408 Capitol, Albany, N. Y.
BOEHM, F. J., Vice-President, Union Electric Light & Power Co., 315 N. 12th St., St. Louis, Mo.
DAHL, THORLEIF CARL HERMANN, Sales Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Pittsburgh, Pa.
DOANE, ROBERT E., Manager, Price & Cost Dept., Standard Underground Cable Co., 17th & Pike Sts., Pittsburgh, Pa.
ESTWICK, CHARLES F., Engineer, General Railway Signal Co., Rochester, N. Y.
HUBERT, EDWARD HATCH, Secretary, Meetings & Papers Committee, A. I. E. E., 33 W. 39th St., New York; res., Hollis, N. Y.
KEARNEY, JAMES R., Director of Electrical Sales, W. N. Matthews Corp., 3722 Forest Park Blvd., St. Louis, Mo.
KINDL, CARL H., Designing Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
PERKINS, ALBERT T., Manager for Receiver, United Railways Co. of St. Louis; Consulting Engr., St. Louis Union Trust Co., St. Louis, Mo.
ROBERTSON, ROBERT ROY, Asst. Engineer, Bureau of Power & Light, 207 S. Broadway, Los Angeles, Calif.

TRESCOTT, JOHN B., Engineer & Manager, Apparatus & Power Div., Commercial Electrical Supply Co., 320 S. Broadway, St. Louis, Mo.

TRANSFERRED TO GRADE OF FELLOW MARCH 13, 1925

SCOTT, CHARLES F., Professor of Electrical Engineering, Yale University, New Haven, Conn.

TRANSFERRED TO GRADE OF MEMBER MARCH 13, 1925

BONNETT, LELAND B.,Inside Plant Engineer, Electrical Engineering Dept., Brooklyn Edison Co., Brooklyn, N. Y.
BUSHER, JOSEPH E., Superintendent, Station Construction, Kansas City Power & Light Co., Kansas City, Mo.
DORAN, JOHN E., Electrical Engineer, Electric Distribution Dept., Union Gas & Electric Co., Cincinnati, Ohio.
OSWALD, ARTHUR A., Engineer, Research Dept., Western Electric Co., Inc., New York, N. Y.
PERRY, O. M., Manager, Windsor Hydro-Electric Systems, Windsor, Ont., Can.
PERRY, WILLIAM W., Electrical Engineer, Binghamton Light, Heat & Power Co., Binghamton, N. Y.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held March 9, 1925, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

HARRISON, JAMES, Engineer, General Engineering Dept., Southwestern Bell Telephone Co., St. Louis, Mo.
PORSKIEVIES, ANTHONY J., Motor Engineer, Electric Controller & Manufacturing Co., Cleveland, O.

To Grade of Member

JENNINGS, F. R., Manager & Owner, F. R. Jennings Co., Detroit, Mich.
ORCUTT, DANIEL P., Assistant Manager, Electric Storage Battery Co., New York, N. Y.
REHMAN, NORMAN J., Assistant Engineer, New York Telephone Co., New York, N. Y.
SIDLE, WALTER P., Bridgeport Service Manager, Westinghouse Electric & Mfg. Co., Bridgeport, Conn.
STAFFORD, HARRY E., Electrical Engineer, Provincial Paper Mills, Ltd., Port Arthur, Ont.
WATERS, WILLIAM A., Electrical Engineer, Manawatu-Oroua Electric Power Board, Palmerston North, New Zealand
WHITEFIELD, WILLIAM I., Superintendent, Lighting & Power, Roanoke Railway & Electric Co., Roanoke, Va.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before April 30, 1925.

Aizanman, L. E., Western Electric Co., Inc., Oakland, Calif.
Alpern, H., J. L. Murrie & Co., Inc., New York, N. Y.
Anderson, H. R., Great Western Power Co., San Francisco, Calif.
Armstrong, W. J., Canadian General Electric Co., Toronto, Ont., Can.
Axmacher, M., New York Edison Co., New York, N. Y.
Barber, E. L., Southwestern Bell Telephone Co., St. Louis, Mo.
(Applicant for re-election)
Bates, J. W., Duquesne Light Co., Springdale, Pa.
Binks, J. E., Public Service Production Co. of N. J., Paterson, N. J.
Blenden, H. A., Southwestern Bell Telephone Co., St. Louis, Mo.
Borislavsky, M. A., Freed-Eiseman Radio Corp., Brooklyn, N. Y.
Breaznell, J. G., Murrie & Co., Inc., New York, N. Y.
Bruyning, E. L., Brytone Radio Laboratories, New York, N. Y.
Burnett, J. A., Lehigh Coal & Navigation Co., Lansford, Pa.
Burroway, A. C., Cincinnati & Surburban Bell Tel. Co., Cincinnati, Ohio
Carpenter, R. C., Bryan Electric Co., Atlanta, Ga.
Carson, R. W., Toronto Hydro System, Toronto, Ont., Can.
Casciati, A. M., T. E. Murray, Inc., New York, N. Y.
Champe, W., Commonwealth Power Corp., Jackson, Mich.
Clark, S. M., New Park Rolling Mill Co., New Park, Ky.; for mail, Cincinnati, Ohio
Cohn, M., Northway Radio Co., Bronx, New York, N. Y.
Congilose, F., Interborough Rapid Co., New York, N. Y.
Conrey, D. W., So. California Telephone Co., Los Angeles, Calif.
Cooper, F. E., Virginia Railway Co., Norfolk, Va.
Copeland, R. M., Partner, Copeland & Copeland, Jersey City, N. J.
Davis, G. P., Philadelphia Electric Co., Philadelphia, Pa.
Davis, H. S., Philadelphia Electric Co., Philadelphia, Pa.
Davis, W. H., Simplex Wire & Cable Co., Chicago, Ill.
Dresel, R., Pacific Gas & Electric Co., Oakland, Calif.
Ducharme, F. L., Canadian & General Finance Co., Ltd., Toronto, Ont., Can.
(Applicant for re-election.)
Eardley, M. V., Bureau of Pr. &. Lt., City of Los Angeles, Los Angeles, Calif.
(Applicant for re-election)
Elliott, J. E., Southwestern Gas & Electric Co., Texarkana, Tex.; Ark.
Falkiner-Nuttall, G. R., (Member), Great Western Power Co., San Francisco, Calif.
Feitig, E. A., Union Gas & Electric Co., Cincinnati, Ohio.
Fluck, E. G. Lawrence Portland Cement Co., Northhampton, Pa.
Foley, J. G., Brooklyn Edison Co., Brooklyn, N. Y.
Fox, H. S., Western Union Tel. Co., Atlanta, Ga.
French, W. P., Puget Sound Power & Light Co., Seattle, Wash.
Fusco, A. A., Freed-Eisemann Radio Corp., Brooklyn, N. Y.
Garner, L. P., University of Illinois, Urbana, Ill.
Geertsen, V. H., Cleveland Union Terminals Co., Cleveland, Ohio
Germain, G. B., South Dakota School of Mines, Rapid City, S. Dakota
Gottfried, H. W., (Member), Siemens-Schuckert Mexico, D. F., Mex.
Green, G. E., Lewis Institute, Chicago, Ill.
Gregory, C. N., General Electric Co., Hartford, Conn.
Grenell, A. F., Illinois Bell Telephone Co., Chicago, Ill.
Groves, W. M., Jr., Southwestern Bell Tel. Co., St. Louis, Mo.
Guest, W. T., Lieut. Signal Corps, U. S. A., Camp Alfred Vail, N. J.
Guy, D. J., (Member), Federal Power Commission, Washington, D. C.
Gysi, M., Brooklyn, Edison Co., Brooklyn, N. Y.
Haley, H. D., General Electric Co., Lynn, Mass.
Hall, W. C., Illinois Bell Telephone Co., Chicago, Ill.
Hall, W. F., New York Calcium Light Co., New York, N. Y.
Harrington, E. C., Staten Island Edison Corp., Livingston, S. I., N. Y.
Hearne, A. W., W. R. Ostrander & Co., New York, N. Y.
Herberger, T. R., Murrie Engg. Co., New York, N. Y.
Hirsch, G. O., General Electric Co., Lynn, Mass.
Howe, D. E., Southern California Telephone Co., Los Angeles, Calif.
Hunsicker, O. F., Champion Coated Paper Co., Hamilton, Ohio
Jones, P. H., Buchanan Rural Telephone Co., Ltd., Buchanan, Sask., Can.
Jones, S. G., Southwestern Bell Telephone Co., St. Louis, Mo.
Kirtley, C. J., Pacific Gas & Electric Co., Oakland, Calif.
Kline, C. A., J. L. Murrie Co., New York, N. Y.
Klingmann, G., Dubilier Radio & Condenser Corp., New York, N. Y.
Klinkert, P. A., Wagner Electric Corp., St. Louis, Mo.
Knowlton, F. K., (Member). M. D. Knowlton Co., Rochester, N. Y.
(Applicant for re-election)
Krasovec, R. A., Hudson Coal Co., Vandling, Pa.
Langwig, F. I., New York Telephone Co., Albany, N. Y.
Litterst, G. H., Public Service Elec. & Gas Co., Newark, N. J.
Little, J. P., Jr., University of Florida, Gainesville, Fla.
Lynn, H. H., Murrie & Co., Inc., New York, N. Y.
Mack, E. J., New York Electrical School, New York, N. Y.
Mahan, W. J., Building Dept., City of New Haven, New Haven, Conn.
Manson, W. B., Holmes Electric Protective Co., New York, N. Y.
McCready, R. I., Otis Elevator Co., Yonkers, N. Y.
McLaughlin, J. L., Precise Mfg. Corp., Rochester, N. Y.
McStroul, L., Electrical Contractor, 1813 Peach St., Erie, Pa.
Menzel, A. F., Caribou Plant, Great Western Power Co., Caribou. Calif.
(Applicant for re-election)
Middleton, R. A., with Joseph T. Fewkes, 137 N. 12th St., Philadelphia, Pa.
Miller. D. B., Coyne Electrical School, Chicago, Ill.
Moore, W. C., Jr., New York Telephone Co., New York, N. Y.
Morrissey, E. J., (Member), Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Mustafa, S., Fairbanks Morse & Co., Beloit, Wis.
Newbury, A. W., General Electric Co., Schenectady, N. Y.
O'Bryan, L., General Electric Co., Schenectady, N. Y.
Oliver, A. J., Ohio Bell Telephone Co., Cleveland, Ohio
Peterson, H. A., Sargent & Lundy, Inc., Chicago, Ill.
Pilgrim, C. O., (Member), Locke Insulator Corp., Chicago, Ill.
Plenge, W. C., Crocker Electric Co., New York, N. Y.
Presley, E. E., The New York Edison Co., New York, N. Y.
Pyle, J. C., Standard Underground Cable Co., Los Angeles, Calif.
(Applicant for re-election)
Pyle, W. A. F., Electrical & Radio Business, Wilmington, Del.
Rapley, F. A., Koppel Industrial Car & Equipment Co., Koppel, Pa.
Rhodes, G. L., Puebla Tramway, Light & Power Co., Puebla, Pue., Mexico

Rossire, H. L., 18 Lattin Drive, Yonkers, N. Y.
Salven, S. A. L., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Sandfort, M., The Pacific Tel. & Tel. Co., San Francisco, Calif.
Sawyer, M. A., The Pacific Tel. & Tel. Co., Los Angels, Calif.
Sayer, H. J., Jarvis Electric Co., Vancouver, B. C.
Schlacks, H. V., Lineman, City of Chicago, City Hall, Chicago, Ill.
Settoon, L. L., United Fruit Co., Bocas, Del Tore, Panama
Shaifer, C. W., General Electric Co., Schenectady, N. Y.
Shapiro, M. H., Brooklyn Edison Co., Brooklyn, N. Y.
Sheely, R. R., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Shor, S., Royal Switchboard Co., New York, N. Y.
Shorrock, E., General Electric Co., Boston, Mass.
Shull, L. P., Standard Underground Cable Co., Chicago, Ill.
Sinex, R. T., Puget Sound Power & Light Co., Seattle, Wash.
Smith, G. C., Salt River Valley Water Users Association, Roosevelt, Ariz.
Stern, S., Experimenter Publishing Co., New York, N. Y.
Stirling, L. B., Shawinigan Water & Power Co., Montreal, Que., Can.
Stonestreet, N. V., Philadelphia Electric Co., Philadelphia, Pa.
Strahan, R. B., 189 Roseville Ave., Newark, N. J.
Terrell, L. S., Western Union Tel. Co., Atlanta, Ga.
Terwilliger, C. V., (Member), Ohio State University, Columbus, Ohio
Thistlewhite, R., Dept. of Elec., Jefferson High School, Los Angeles, Calif. (Application for re-election)
Tillotson, P. M., Edison Electric Illuminating Co., Boston, Mass.
Tzougros, G. J., Public Service Electric & Gas Co., Newark, N. J.
Van Eyk, P., New York Telephone Co., New York, N. Y.
Velasco, J., Jr., Milwaukee Electric Railway & Light Co., Milwaukee, Wis.
Vogel, P. J., Dept. of Public Service, City of Los Angeles, Los Angeles, Calif.
Vollmer, K. J., Molony Electric Co., St. Louis, Mo.
Wagner, R. T., (Member), General Electric Co., Schenectady, N. Y.
Wallin, M. R., Union Electric Light & Power Co., St. Louis, Mo.
Weeks, O. B., Murrie & Co., New York, N. Y.
Wennerstrom, A. W., General Electric Co., Erie, Pa.
White, T. C., McClellan & Junkersfeld, Inc., St. Louis, Mo.
Whitlock, C. H., Samson Cutlery Co., Rochester, N. Y.
Wilson, R. D., Ohio Public Service Co., Alliance, Ohio
Woods, H. J., Missouri Inspection Bureau, St. Louis, Mo.
Yates, G. A., Habirshaw Electric Cable Co., Inc., Yonkers, N. Y.
Zink, M., Borchard Affiliations, New York, N. Y.
Total 125

Foreign

Alauddin, R., G. I. P. Ry. Works, Jhansi, U. P., India
Fujino, S., Kumamoto Electric Co., Kumamoto, Japan
Grainger, A. H., with W. H. Alexander, Belfast, Ireland
Hansen, H. H., Compania Azucarera El Ejemplo, Central El Ejemplo, Humacao, Porto Rico.
Kozai, Y., Railway Dept. of Japanese Gov't., Tokyo, Japan.
Kwong, F. K., Toi-shan Electric Light & Power Co., Ltd., Hongkong, China.
Kynaston, B. H. J., A. Holt & Co., Liverpool, Eng.
Potter, W. H., New Zealand Government, Hamilton, N. Z.
Raven-Hart, R. J. M., (Member), Transandine Railways, Los Andes, Chile, S. A.
Young, J. F., Kilburn & Co., Calcutta, India
Total 10

STUDENTS ENROLLED
MARCH 13, 1925

Allen, Roger W., Mass. Institute of Technology
Arnell, John C., Brooklyn Polytechnic Institute
Bell, Ralph W., Kansas State Agricultural College
Bidne, Bernell, South Dakota State College of A. & M. Arts
Blazer, James P., Eng. School of Milwaukee
Brady, Eugene L., Kansas State Agricultural College
Breithaupt, C. Crothers, Georgia School of Technology
Briden, Osborne W.. Brown University
Briggs, Frank S., Engg. School of Milwaukee
Brown, John H., Brown University
Carlson, Elmer T., Northeastern University
Cerf, Edgar A., Jr., Georgia School of Technology
Chen, T. Y., Harvard University
Chow, Y. W., Mass. Institute of Technology
Clark, Edwin L., State College of Washington
Cobb, Lewis E., Northeastern University
Collins, Willis C., Denver University
Coons, Donald L., University of Idaho
Cooper, Roland R., South Dakota State College
Cottrell, Burdett P., University of Arizona
Cram, Esmond B., Clarkson College of Technology
Crawford, Royce, C., Alabama Polytechnic Institute
DeShazo, Jefferson S., Cornell University
Dickerhoff, James F., Pennsylvania State College
Dulley, William C. W., Mass. Inst. of Technology
Duncan, William S., University of Illinois
Eatherton, Clarence Z., Ohio Northern University
Ebert, Emil F., University of Wyoming
Etienne, Alexander J., Rensselaer Polytechnic Institute
Evans, Clifford A., Pennsylvania State College
Ewald, Louie J., Engg. School of Milwaukee
Fairburn, Abraham J. B., Penn. State College
Faruqui, Mumtaz A., Oregon Agricultural College
Fleak, Roy E., University of Arkansas
Floyd, Middleton B., Georgia School of Technology
Gamble, William, South Dakota State College
Garbrick, J. Henry, Pennsylvania State College
Gilmore, Rolf B., University of Wyoming
Godley, Edgar B., Rice Institute
Gottschall, Sidney E., City College of New York
Graybrook, H. B., Purdue University
Grzeskowiak, Lawrence S., University of Wyoming
Haendler, Anton T., Northeastern University
Helgason, Arni, University of Wisconsin
Hentschel, Herman F., Engg. School of Milwaukee
Hill, R. Frank, Virginia Military Institute
Hinckley, Alfred D., Columbia University
Hinckley, W. G., Purdue University
Hosking, Harry, Newark Technical School
Howe, Ramon R., Purdue University
Jackson, Earl E., University of Oklahoma
Jackson, William E., Brown University
Johnson, Hobart M., Washington State College
Jones, Herbert R., Jr., Pennsylvania State College
Jones, Thomas L., Harvard University
Karr, Herbert S., University of Washington
Karsten, Edgar J., University of Iowa
Keeler, Mark V., Purdue University
Keim, Frank G., Lafayette College
Kent, Oliver C., Engg. School of Milwaukee
Killian, Thomas J., Mass. Institute of Technology
King, Alfred T., Drexel Institute
King, Ernest C., Stanford University
King, Ralph E., Purdue University
Kirkpatrick, W. V., Purdue University
Kreer, John G., Jr., University of Illinois
Krieble, Kieth N., Oklahoma A. & M. College
Landesberg, Martin M., Brooklyn Polytechnic Institute
Larson, O. Theodore, Rensselaer Polytechnic Institute
Laycock, John K., Jr., Georgia School of Technology
LeRoy, Holden M., Oregon Inst. of Technology
Lewin, George, Cooper Union
Lewis, Richard C., Stanford University
Linn, Floyd A., Purdue University
Lippert, Leo H., South Dakota State College
Locke, Walter J., South Dakota State College
Loosen, Max H., Oklahoma A. & M. College
Ludwig, Gerald C., University of Notre Dame
MacNeil, Charles I., Drexel Institute
Makarov, Alexis, University of Arizona
Martin, Ben F., Engg. School of Milwaukee
Mayes, Leonard E., University of Missouri
Mee, Charles L., University of Illinois
Mielke, Irven S., Engg. School of Milwaukee
Miller, Harry, University of Toronto
Miner, J. Durward, Jr., Brown University
Morse, John A., Worcester Polytechnic Institute
Morton, George A., Mass. Institute of Technology
Morton, William, South Dakota State College
Murray, Everett M., University of Wyoming
Nace, Melvin F., Johns Hopkins University
Nadler, Charles S., Cooper Union
Needham, Gordon H., Brown University
Newcomer, Garfield H., Penn. State College
Oehler, John F., Rensselaer Polytechnic Institute
Olney, Hendrick A., Brown University
Ossinovsky, Joseph, Rensselaer Poly. Inst.
Owen, J. Clements, Virginia Military Institute
Patton, Howard G., Newark Technical School
Pepoon, Philip W., Jr., University of Wyoming
Peterson, Arthur F., Columbia University
Peterson, Chester, Mass. Institute of Technology
Petruska, John, Rensselaer Polytechnic Institute
Pingel, Alfred W., Engg. School of Milwaukee
Potter, Vernon M., Rensselaer Polytechnic Institute
Price, Gordon F., Georgia School of Technology
Reindle, Alfred F., Engg. School of Milwauke
Richards, John H., Stanford University
Rietz, G. A., South Dakota State College of A. & Arts
Robbins, Charles L., Rensselaer Polytechnic Institute
Rommel, Edward J., University of Michigan
Ross, Ladner V., Oregon State College
Ruzich, John L., Armour Institute of Technology
San, C. J., Purdue University
Sangster, F. Allan, University of Toronto
Schonfeld, Martine F., Purdue University
Schuler, Reginald G., Armour Institute of Technology
Scripps, William W., Mass. Inst. of Technology
Sease, Will S., Yale University
Seaverson, Oswald, University of Wyoming
Seim, Edward R., Mass. Inst. of Technology
Servatius, Oswald F., Chicago Technical College
Setzer, Martin W., Engg. School of Milwaukee
Shanley, Fred D., Ohio Northern University
Shinbur, Virgil D., University of Wyoming
Sipkin, George, Cooper Union
Skeats. Wilfred F., Columbia University
Sliney, David, Cooper Union
Smith, George R., Tri-State College
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Vance, Clarence G., Michigan Agricultural College
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Wilsey, Kenneth C., Rensselaer Polytechnic Institute
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Total 80.		

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies.

Sine Wave Generator.—Bulletin 42567, 4 pp. The description includes photographs, charts, diagrams and tables in addition to the text. The various testing applications of the generator are explained. General Electric Company, Schenectady, N. Y.

Transformers.—Bulletin 2041, 4 pp. Describes Pittsburgh polyphase transformers and the advantages of this type over single-phase transformers for three-phase generation. Pittsburgh Transformer Company, Columbus & Preble Aves., Pittsburgh, Pa.

Load Indicators.—Bulletin. Describes central station load indicating systems, including many illustrations of the various types of load and period Indicators, manual controls and totalizing watt-meter operated automatic control. Chas. Cory & Son, Inc., 183 Varick Street, New York.

Fans.—Bulletin 143, 18 pp. Describes the new, complete line of Wagner electric fans. Wagner Electric Corporation, St. Louis, Mo.

Blowers.—Bulletin 1801, 72 pp. Describes American "Sirocco" fans and blowers, giving complete specifications for all types. American Blower Company, Detroit, Mich.

Motor Maintenance Equipment.—Catalog 6, 16 pp. Describes commutator slotting and grinding equipment, including undercutters, slotters, grinding tools, commutator stones, blowers for cleaning, commutator cement and insulating varnish. The Martindale Electric Company, 11737 Detroit Ave., Cleveland, O.

Lighting Units.—Catalog. Describes the complete line of Holophane lighting units, and includes several new developments brought out in the last year. Among these are the No. 944, 200 watt window reflector, the No. 980 watchman circuit lighting unit, and the C-2172 corridor lighting unit. The Holophane Glass Company, 342 Madison Avenue, New York.

Transmission Towers.—Book, 182 pp. A handsome volume, which contains much vaulable information not only on the construction of transmission towers, but calculations and tables for erection of complete lines. Profusely illustrated with photographs of typical installations. American Bridge Company, Frick Building, Pittsburgh, Pa.

Lighting Data.—A series of interesting bulletins on lighting, as follows: Bulletin L. D. 154, 50 pp., "Adequate and Efficient Motor Bus Lighting;" Bulletin L. D. 153, 28 pp., "Electric Light on the Farm;" Bulletin L. D. 119B, 24 pp., "The Manufacture of the Edison Mazda Lamp;" Bulletin L. D. 113A, 32 pp., "Miniature Edison Mazda Lamps." Edison Lamps Works of General Electric Company, Harrison, N. J.

Remote Control Motor Starter.—Bulletin 219, 8 pp. Describes a new and unusual automatic remote control starter for squirrel cage motors, in capacities from 7½ to 60 h. p. Among the features of the new device are that all operating contacts are made and broken under oil; overload relays have oil-immersed contacts adjustable for both time and load setting; the single lifting magnet used is energized only during starting; quickly installed and connected; and worn contacts can be easily replaced. Crocker-Wheeler Company, Ampere, N. J.

Robinson Interlock.—Bulletin 105-29-B. Describes a device for preventing accidental opening of disconnecting switches while under load, by station personnel or from malicious tampering. The interlocks assure proper sequence operation of electrically controlled oil switches and the disconnecting switches connected in series with them, at the same time providing safety against contact with live instrument transformers or other electrical equipment in buss and feeder cells. Chas. Cory & Son, Inc., 183 Varick Street, New York.

Small Motor Lubrication.—Bulletin 568, 4 pp. Describes the system of lubrication for small "Century" motors, consisting of a number of continuous strands of pure wool yarn permitting capillary action to assert itself completely. Moreover, the filtering properties of the yarn assure that the oil is completely filtered before delivery to the bearing surface. In addition, the use of the yarn system prevents danger from leaks from an oil well, since the material will hold in suspension sufficient oil to properly lubricate a "Century" fractional horse power motor for at least one year's continuous operation. The total capacity of the small motor ring oiler type of oil well is increased about 100% and positive lubrication under all conditions, even at extremely low room temperature, is assured. Century Electric Company, 1827 Pine St., St. Louis, Mo.

NOTES OF THE INDUSTRY

The Okonite Company, Passaic, N. J., manufacturers of insulated wires and cables, has opened a sales office in St. Louis at 444 Frisco Building, in charge of L. R. Mann.

Renewable Fuses.—A new line of fully approved renewable cartridge fuses is announced by the Trico Fuse Manufacturing Company, Milwaukee, Wis., manufactured in all standard sizes from 0 to 600 amperes. The company is a pioneer in powder-packed, time-limit renewable fuses with the air cushion feature, which it is claimed were the first to pass the Underwriters' Laboratory test requirements.

The Crocker-Wheeler Company, Ampere, N. J., has opened an office at Atlanta, Ga., 101 Marietta Building, in charge of George D. Anderson, Jr. The Baltimore office has been discontinued. S. M. Conant, formerly in charge of the latter office has been appointed assistant sales manager, and is now located at Ampere.

The Pittsburgh office, in charge of J. R. Lewis, has moved from the Henry W. Oliver Building to the Dravo Building, 300 Pennsylvania Avenue. This office will have a warehouse in which a large stock of motors will be carried.

Two Million-Volt Testing Outfit for Leland Stanford University.—Looking forward to the time when power must be transmitted for hundreds of miles to meet the demands of the San Francisco territory, Leland Stanford University has ordered a 2,000,000-volt testing outfit from the General Electric Company. This set, which will operate at the highest voltage ever produced at commercial frequency, has been ordered by the university so that it can attempt to solve the problems of extremely high voltage transmission well in advance of the requirements.

It is expected that within ten years all of the available water power (1,600,000 h. p.) within 200 miles of San Francisco will have been developed. For the increased population that is sure to follow, further power must be obtained from the Klamath and Rogue Rivers, 400 miles distant, and from the Columbia River basin, 700 miles to the north. These rivers can furnish approximately 2,700,000 h. p. Economical use of this power will require much higher transmission voltage than used at the present time, or improved transmission methods must be developed.

A modern laboratory for housing the apparatus will be provided and adjacent to the building will be a large plot on which a transmission line several miles in length may be constructed for carrying on the tests. Professor Harris J. Ryan will be in charge of the work and will devote his entire time to research in the new laboratory.